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REPORTS OF THE SWEDISH DEEP-SEA EXPEDITION 1947—1948

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HANS PETTERSSON
SCIENTIFIC LEADER OF THE EXPEDITION

VOLUME VI

Sediment Cores from the West Pacific

FASC. I

GÖTEBORG
ELANDERS BOKTRYCKERI AKTIEBOLAG

REPORTS OF THE SWEDISH DEEP-SEA EXPEDITION. VOL. VI
SEDIMENT CORES FROM THE WEST PACIFIC. NO. 1

DIATOMS FROM EQUATORIAL PACIFIC CORES

BY

R. W. KOLBE

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Introduction

During the cruise of the Swedish Deep-Sea Expedition 1947—1948 a large number of deep-sea cores were collected. With the aid of the KULLENBERG core sampler, deep-sea cores were collected of, so far, unparalleled length, some of the cores discussed in the present paper measuring up to 13 m. G. ARRHENIUS, the geologist of the Expedition, when investigating the cores from the equatorial part of the East Pacific found that a great centric diatom dominated in certain levels of the cores. ARRHENIUS asked the present writer to determine the species. It proved to be *Coscinodiscus nodulifer* A. Schm. Further it was found that *C. nodulifer* exhibited in various levels of the cores a somewhat peculiar characteristic: layers with larger specimens dominating alternated at certain intervals with layers containing smaller individuals. As this circumstance might be important for the geological investigations, ARRHENIUS proposed a biometric survey of the total material with regard to the size variation of *C. nodulifer*.

The unique material invited to further investigations on its diatom flora and I was therefore very pleased to accept the offer of Professor HANS PETTERSSON, leader of the expedition, to make a general survey of the diatoms of the Equatorial Pacific cores besides those from the East Pacific which ARRHENIUS had investigated.

1. Material

From cores with their natural moisture preserved, samples 1.5—2 cm thick, were cut at carefully marked levels. (With regard to the complicated and ingenious methods of conservation of cores and the cutting out of samples, cf. ARRHENIUS 1952, 4, p. 1 ff). The samples were usually taken at distances of 10 or 20 cm according to ARRHENIUS' wishes. In certain cases only a few specimens were taken out of a core. The complete investigation covered 459 samples from 26 cores represented in the table 1.

TABLE 1.

No. of Cores	Geographic position	Depth m	Examined section of Core cm	Number of samples
38	2° 52′ S, 89° 50′ W	3225	6— 400	21
39	2° 44′ S, 92° 45′ W	3617	2— 528	34
40	1° 04′ N, 93° 20′ W	2827	150— 310	5
41	3° 20′ N, 97° 53′ W	3401	150— 405	7
42	5° 42′ N, 101° 41′ W	3200	20— 409	5
43	6° 21′ N, 103° 42′ W	3465	197— 320	5
44	6° 55′ N, 104° 46′ W	3515	348— 420	3
45	7° 40′ N, 106° 21′ W	3725	252— 301	2
46	8° 22′ N, 108° 0′ W	3800	299— 350	2
47	9° 14′ N, 109° 39′ W	3567	249— 401	4
58	6° 44′ N, 129° 28′ W	4440	0— 978	45
59	3° 05′ N, 133° 06′ W	4370	0— 967	52
60	1° 35′ N, 134° 57′ W	4540	10—1011	62
61	0° 06′ S, 135° 58′ W	4475	0—1023	57
62	3° 00′ S, 136° 26′ W	4520	0— 620	33
74	0° 29′ S, 151° 33′ W	4545	4—1342	108
75	0° 20′ N, 150° 36′ W	4405	201— 398	4
76	3° 45′ N, 149° 44′ W	5155	4—1342	68
91	2° 56′ S, 171° 18′ O	4120	198— 398	4
93	1° 20′ S, 167° 23′ O	3965	198— 398	4
95	0° 34′ N, 159° 59′ O	2880	198— 396	4
96	0° 52′ N, 157° 04′ O	2200	198— 392	4
97	0° 48′ N, 154° 46′ O	3030	198— 398	4
98	1° 40′ N, 152° 37′ O	3670	198— 398	4
105	2° 38′ N, 139° 34′ O	4275	200— 398	4
107	4° 25′ N, 130° 40′ O	4445	198— 397	4

On closer examination, cores 44, 91, 95 and 96 contained no diatoms. The distribution of cores in the Pacific is demonstrated on the chart in Fig. 1.

The cores examined originate from areas near the Galapagos Islands to a point north of the western end of New-Guinea. The fact that they are not uniformly distributed over this vast area is partly due to the choice of samples being made from certain geological points of view.

2. Methods

As the samples contained practically no more organic matter, it was not necessary to make the usual treatment with H_2SO_4 or HNO_3. In order to get rid of the lime (which formed the bulk in most of the sediments), the samples were treated with dilute hydrochloric acid; this was adopted as the standard method. The further treatment was performed by careful decantation after definitely timed settling-periods (3 × 40 minutes with glass cylinders 10 cm in height and 4 cm in diameter). The mounting was made in Hyrax or Sirax. Special attention was paid to the absolute cleanliness of the vessels and pipettes[1]).

The biometric investigation of *Coscinodiscus nodulifer* — originally the main problem — was performed in the usual way. To begin with, different size diameter ranges were selected, differing by 10 μ, *e. g.* 30 μ, 40 μ, etc.; all *C. nodulifer* valves which appeared when handling the mechanical stage (at a medium magnification) were measured by means of a micrometer eye-piece and quoted and summed up under the corresponding headings of the record. Fragments of valves, showing less than a semi-disc were ignored; experiments proved that this procedure in our case, involved the least error. On every slide — corresponding to one sample each, that is one core level — 300 to 350 specimens were measured and counted. The sums of the various headings in the record were converted into percentages of the sum total of specimens counted (in each sample): thus the

[1]) For cleaning the pipettes — the most frequent source of inaccuracies — a procedure proved suitable, which the writer has used with success for many years. Pipette-tubes with an external diameter of 8 mm were drawn out at one end so as to form a blunt cone with an aperture of about 1.5 mm; after use, such pipette-tubes are easily cleaned with a pipe cleaner which also cleans the aperture.

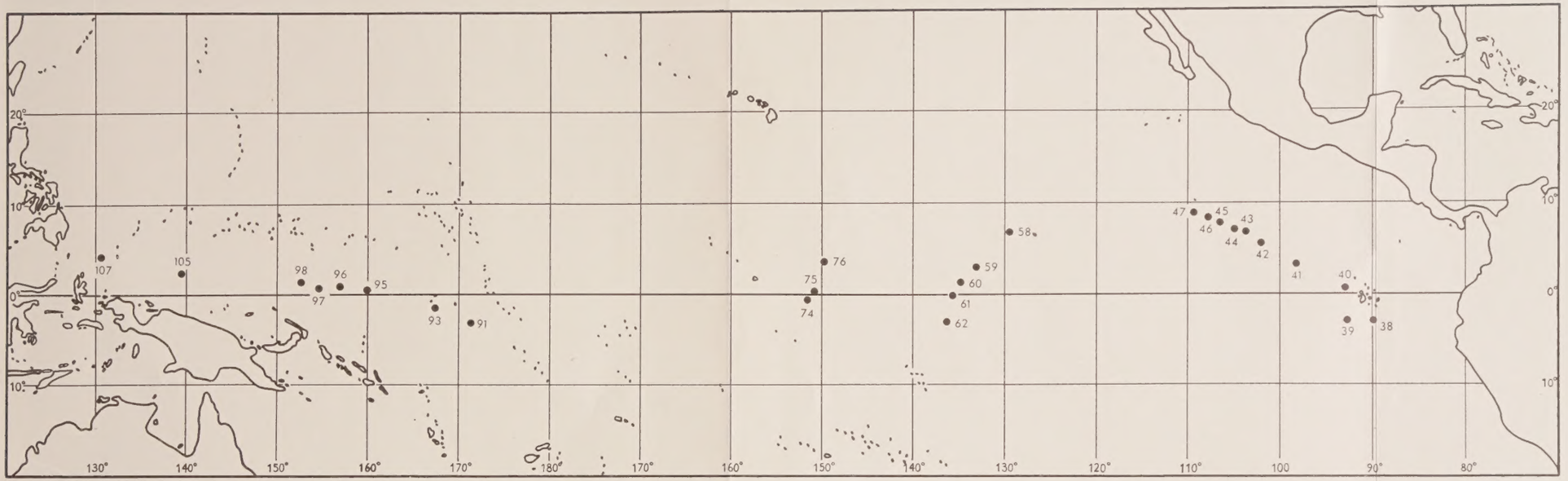
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Fig. 1.

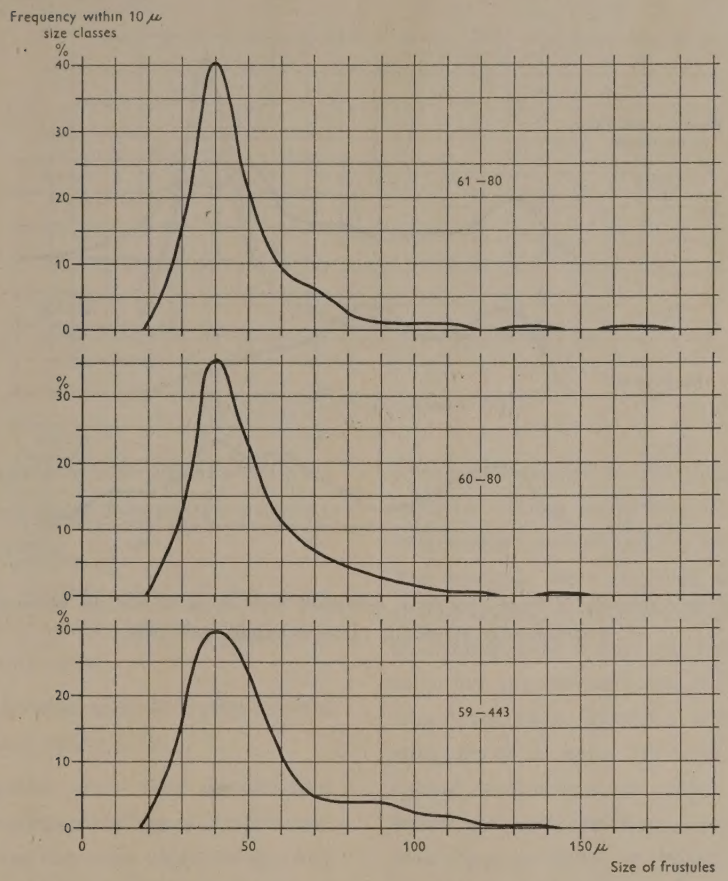


Fig. 2. Examples of size frequency distribution with a marked relative dominance in the size group 30—50 μ. (After G. ARRHENIUS 1952)

percentage values found are independent of the number of specimens measured and comparable with the results from the other samples.

A graphical presentation of these percentages results in a frequency diagram. The following examples of frequency diagrams (fig. 2 and 3) are taken from ARRHENIUS (1952, 1.9.2.1 and 1.9.2.3); the abscissae of the diagram represent the diameters in μ of *Coscinodiscus nodulifer* in a single core level and the ordinates — the percentual frequency of the corresponding size ranges. The small numbers in the middle part of the diagrams indicate the number of the core and the depth of the level in cm.

At the geological survey of the Swedish Deep-Sea Expedition the frequency curves of *Coscinodiscus nodulifer* partly formed the basis for discussing the stratigraphy of the bottom sediments; they have thus been used in ARRHENIUS' (1952) work. All frequency curves of a core were combined to an isoplethic space-diagram as shown in Fig. 4.

For confirmation and in order to check errors due to the technique of preparation some tests were made in the course of the investigation.

The diagrams (fig. 5 and 6) show the result of counting 350 samples of *Coscinodiscus nodulifer* in two levels (40 cm and 259 cm sediment depth) of the same core (59).

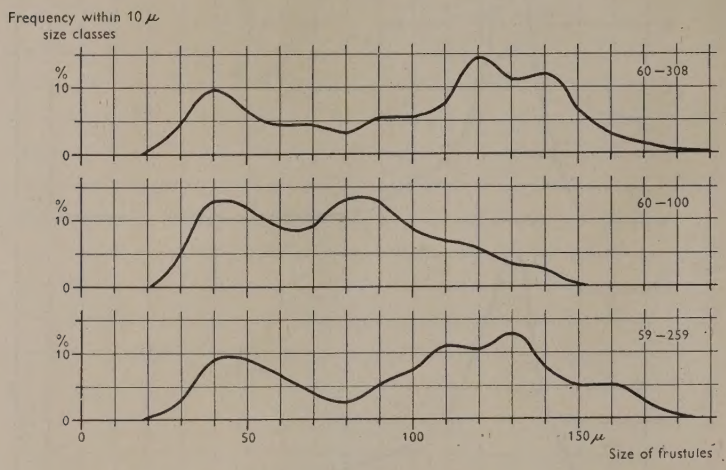


Fig. 3. Several secondary maxima in large sizes have developed and owing to this the percentage of small valves is considerably decreased. (After G. Arrhenius 1952)

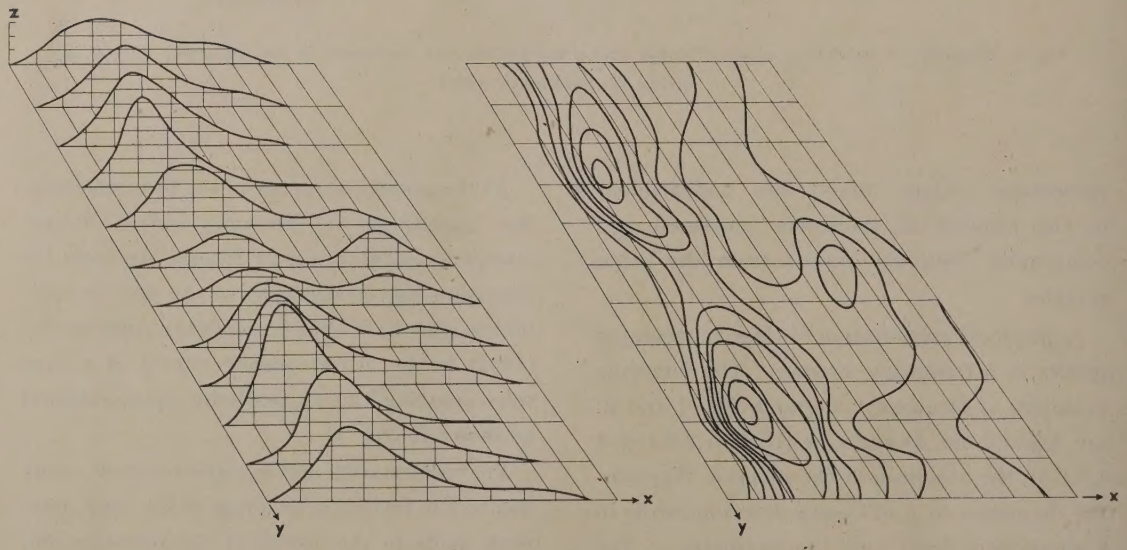


Fig. 4. (After G. Arrhenius 1952)

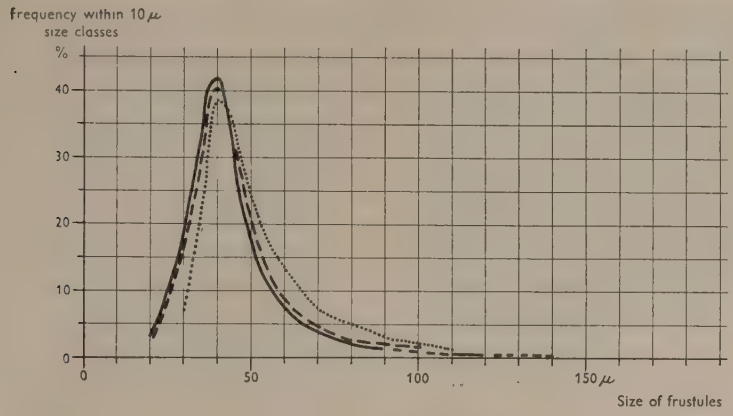


Fig. 5. (After G. Arrhenius 1952)

The diagrams are to be interpreted as follows:

a. (full line) after a single decantation in a great quantity of water;

b. (dashed line) another piece of the same sample taken by another person and treated in the same way as a;

c. (dotted line) the same piece as b after normal decantation (see above p. 4).

The two diagrams show that decantation causes a certain unimportant loss of small forms, but — and this was the main object of my test — the character of the curve is unchanged and the critical maxima are in the same positions. Further it is shown, by comparing the curves for two different zones (a—b), that the distribution of *Coscinodiscus* in the cross section of the core is rather uniform.

In some cases the number of *Coscinodiscus nodulifer* valves was determined in 1 g of the dry sediment. In these cases the following method was employed: 250 mg of the air-dried sediment were treated with HCl and decanted; water was added to the suspension until a suitable volume (according to the quantity of valves) was reached, usually 50, 100 or 200 ccm. The contents were violently stirred and, while still in motion, 0.4 ml suspension were extracted by suction with a specially constructed micro-injection syringe and immediately transferred to a cover glass. Then the syringe was washed with distilled water and the washing water spread out on another cover. After drying at room temperature the usual procedure of mounting in Sirax or Hyrax followed. The total of the valves counted on both covers was finally brought into relation to 1 g of the dry sample by multiplication with the dilution coefficient.

In order to avoid mistakes such as double counting or omittance of specimens (the error is magnified on account of the high dilution coefficient) the covers were provided with a system of scratched parallel lines at a distance from each other corresponding to the field of vision of the optical system used.

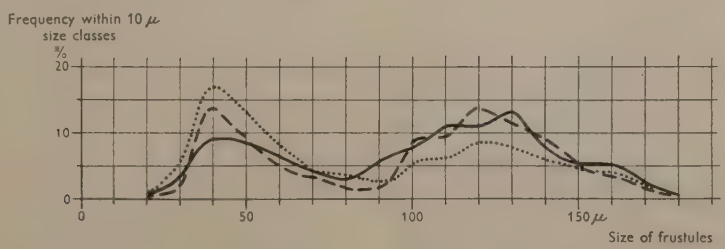


Fig. 6. (After G. Arrhenius 1952)

3. General Remarks on the Material

Even on a cursory examination of the core samples of the equatorial Pacific, the *scarcity of species* and the *monotony* of the diatom flora is obvious. One notices the absence of the most frequent delicate planktonic forms as, *e. g.*, representatives of the genus *Rhizosolenia*, *Bacteriastrum*, *Chaetoceros*, *Lauderia*, *Planktoniella* and many others, even species with thick valves such as *Coscinodiscus marginatus*, several other species of *Coscinodiscus*, *Endictya*, *Stephanopyxis* etc. Instead, some of the ± rare species, which were comparatively rarely noticed by former observers in the plankton of warmer seas, are found in great abundance: in the first place *Coscinodiscus nodulifer* which dominates all diatomiferous core samples, but also such species as *Asteromphalus elegans*, which is present in 55 % of all cores and often in a great number of individuals; further, *Actinocyclus ellipticus* var. *elongatus*, *Asteromphalus hiltonianus* and some others. The list of species is uniform: in most of the cores and their various levels, down to great depths of sediment it is the same — with the exception of Core 76, to which we shall return.

At first sight these facts seem to be rather peculiar. An explanation is found if we consider that the diatoms of the bottom samples do not represent a community, but a thanatocoenosis (Wasmund 1926).

The diatoms as purely autotrophic plants are restricted to the upper euphotic water layers. Their biocoenosis in mid-ocean is the plankton. Here they develop and form — according to the ecologic conditions of the locality — a population, that is characteristic for the given locality. The dead individuals slowly sink to the bottom; the protoplasm is gradually destroyed by bacteria and other organisms, the valves, on the other hand, during their settling, are exposed to the dissolving effects of the seawater. The corrosion effects differ according to the physico-chemical qualities of the water, which may change considerably during the various geologic periods. The valves deposited on the ocean floor may also be attacked by chemical agents; the mixing of the upper sediment strata by mud-feeding animals may also be of importance.

During the long lapse of time which is certainly necessary for the diatom valves of the upper ocean strata to get deposited on the ocean floor, a transport of diatoms takes place in a horizontal direction. This transport is effected by currents in the upper water layers (cf. Lohman 1941, p. 62), as well as by deep-sea currents, which may run in an opposite direction to the surface currents, and finally the transport may be caused by diatom-eating animals which in their turn are being consumed by other — larger — animals. The rate of sinking[1]) and the distances covered by diatoms, when carried along horizontally, cannot be estimated, even approximately.

Four phases may thus be distinguished which finally lead to a thanatocoenosis:

Biocoenosis (plankton, production of diatoms)

Sinking (primary corrosion)

Horizontal transport

Deposition (secondary corrosion)

Thanatocoenosis (final accumulation of diatoms of a certain region).

The valves of plankton species are, as is well known, quite different with regard to their resistance against corrosion (see further). On account of this, a sort of physico-chemical *selection* takes place during the sinking, during the horizontal transport and possibly during the deposition; thus the list of diatoms from the ocean floor may present an entirely different aspect than the one of the corresponding upper water layers. In short it may be said:

[1]) Lohman (1941, p. 62 ff.) tried to study experimentally the rate of sinking of diatom valves; he found, as he states, by applying his figures to natural conditions, quite incongruent values.

a. The biocoenosis of an ocean area need not at all correspond to its thanatocoenosis;

b. The thanatocoenosis is stipulated by the plankton population as well as by the capacity of the particular species for resistance against the physico-chemical factors of the biotope, which in their turn are subject to alterations during geological periods;

c. Further the thanatocoenosis is influenced by the horizontal transport of the sinking diatoms and its duration. The horizontal transport again, is mainly the result of currents which also, at different periods, may be subject to various alterations.

d. The depth of the ocean basin and consequently the duration of the sinking is surely of some importance for the character of the selection. Ocean depth too, is a variable factor if geological spans of time are considered.

In the present material the general effect of the corrosion consisted in a kind of differential solution: some species were strongly attacked, others less and still others were completely dissolved. This is a phenomenon well known to investigators of foraminifera (cf. SCHOTT 1935, quoted by ARRHENIUS 1952).

No separate effect of the secondary corrosion was noticed in my material. This effect could be observed if the relative frequencies of single species on the surface of the floor were different from the frequencies in the deeper layers of the core[1]). This was not the case in the samples investigated. It should not, however, be taken as proof of the non-existence of secondary corrosion, the upper layers of the cores usually being damaged when taken out; even the upper cm of sediment are, on the other hand, deposited over a period of time which must be counted in thousands of years. To what extent the secondary corrosion in this case may have added to the forming of a thanatocoenosis of diatoms is impossible for us to decide.

The selective effect of the corrosion, mentioned before, often shows in the complete inversion of the frequency values: species which may abound in the plankton become scarce or *vice versa*. This feature is most obvious in the dominance and constancy of *Coscinodiscus nodulifer* in most bottom samples.

4. Coscinodiscus nodulifer

Dominance and constancy. The abundance of *Coscinodiscus nodulifer* in almost all cores from the Equatorial Pacific is contradictory to previous statements in literature. This does not mention anywhere that *C. nodulifer* belongs to the dominating or even more frequent species of the plankton or the bottom sediments; it is true that for early authors it was sufficient to give a determination of the species and to mention its locality — mostly imperfectly; — regarding earlier statements see DE TONI 1891. More recent data were obtained exclusively from such expeditions, which made investigations on diatoms (for the sake of convenience, only the expedition-ships and the investigators of diatoms are quoted, detailed statements are to be found under References):

Challenger ..... (CASTRACANE, 1886)
Albatross ..... (MANN, 1907, 1925, 1925a, 1937)
Valdivia ..... (KARSTEN, 1907)
Belgica ..... (VAN HEURCK, 1909)
Belgica ..... (MEUNIER, 1910)
Pourquoi-Pas ..... (PERAGALLO, 1921)
Dan. Oceanogr. Exp. (PAVILLARD, 1926)
Gauss ..... (HEIDEN & KOLBE, 1927)
Discovery ..... (HENDEY, 1937)
Lord Kelvin ..... (LOHMAN, 1941)

The last mentioned work (LOHMAN 1941) gives the most complete data so far available of the occurence of *Coscinodiscus nodulifer* in the bottom samples of one of the oceans, the Atlantic. LOHMAN examined nine cores from

[1]) According to ARRHENIUS (1952, 1.12. 5 p. 86) it is probable that the mixing of the sediment by mud scavengers seldom affects a layer more than 5 cm thick.

the North Atlantic from depths between 1955 and 4 820 m; the length of the cores varied between 1.24 and 2.97 m. Thirty-nine levels of this material contained diatoms and of these, nine levels contained *C. nodulifer*. In three of the layers this species was abundant, in the other six it was scarce. Even in this thoroughly investigated material did *C. nodulifer* not belong to the dominant and constant species.

Contrary to this is the exceptional abundance of *Coscinodiscus nodulifer* in all bottom samples treated in this paper. The species is present in all diatomiferous cores; in most levels it is a very common form and in many layers it reaches absolute dominance over the rest of the species.

Resistance against corrosion. From the above observations it follows that *Coscinodiscus nodulifer* does resist corrosion in a marked degree. Most diatomists think that the thickness of the wall has a direct relation to the resistance to corrosion. The valves of *C. nodulifer* are certainly rather robust, but not thicker than other frequent forms in bottom samples, such as *C. lineatus, C. marginatus* or *Hemidiscus cuneiformis* which, however, corrode more easily. Very probably *Coscinodiscus nodulifer* has a specific power of resistance to corrosion not dependent solely on the thickness of its cell wall. This conclusion is supported by Cores 43, 95 and 96 in which almost all organic silica is corroded past recognition. All — even the most frequent — diatoms and even the relatively robust radiolaria in the three cores mentioned, were practically dissolved. Only *C. nodulifer* remained in single specimens. These specimens were soft, membranaceous structures, collapsing when dried and showing only faint traces of the valve structure which, nevertheless, could definitely be identified. The entire silica seemed to have been dissolved, leaving only a kind of matrix.

The regular and relatively frequent occurence of such delicate forms as *Actinocyclus ellipticus* var. *elongatus* and *Asteromphalus elegans* in the bottom samples, speaks also in favour of a certain specific corrosion resistance. The first named — extraordinary hyaline — form has, moreover, already been met with at different localities of the Pacific by Castracane (1886 and described as *Willemoësia*).

Number in 1 g sediment. One of the results of our studies on *Coscinodiscus nodulifer* may be of general interest. For geological purposes the number of valves of *C. nodulifer* in 1 g air-dried sediment was to be calculated. The counting was undertaken as previously described (see page 7) and resulted in the following figures:

1 g sediment of Core 60, 229 cm depth of sediment contains 1,043,000 valves.
1 g sediment of Core 60, 240 cm depth of sediment contains 1,070,000 valves.
1 g sediment of Core 60, 257 cm depth of sediment contains 1,125,000 valves.
1 g sediment of Core 60, 279 cm depth of sediment contains 1,016,000 valves.

Thus *one gramme* of the examined *sediment contains* about 1 *million Coscinodiscus-valves;* even assuming that the average size of the valves be 50 μ (average diameter), these valves would, if put together, cover a distance of 50 meters.

Size variation. The biometric investigation to establish the size variation of *Coscinodiscus nodulifer* was the most extensive and most time-consuming part of the present work. It was first performed by the writer alone and later with the efficient help of four collaborators. First the author trained them in the determination of *C. nodulifer* and their determinations were checked at intervals.

Altogether more than 120.000 single valves of *C. nodulifer* were measured and recorded and represent undoubtedly the most extensive biometric investigation made on a diatom.[1])

[1]) In this connection we refer to a biometric examination by Hart, 1937, who worked on material from the »Discovery» Expedition and studied the size variation of *Rhizosolenia curvata* (3,024 individuals) observing fluctuations of diameter between 20 μ and 135 μ.

The results of this biometric investigation (cf. MAILLEFER, 1907) as mentioned above, were included by ARRHENIUS 1952 and the following discussions contain some general observations and reflections.

My studies were undertaken on an exceptional material and showed in thé first place a much greater range of size variation of *C. nodulifer* than known before. The diameter fluctuated between 11 μ and 210 μ and a distinctly marked average size of 30 μ to 50 μ could be observed. The density of the areolation, however, was comparatively constant: whereas the individuals of the most frequent size ranges (30 μ—50 μ) showed about 4—5 areolae in 10 μ, the density of areolation increased to 6 in 10 μ with dwarf specimens and decreased in the largest specimens to 3 in 10 μ.

The fact that populations of »large» *C. nodulifer* alternate with populations of »small» individuals in certain geological periods (see Fig. 2 & 3) is interesting in itself from a biological as well as from a geological point of view.

Diagrams of the size variation (or the variation of any other property) with two or more peaks, generally indicate that a population is not uniform but consists of two or more genotypic units (species, races, forms or whatever they may be called in terms of taxonomy). In proportion to the changes in life conditions one or the other type may reach a stronger development without the other being completely suppressed. The presence of two different morphologically undistinguishable races within the population of *C. nodulifer* could explain the two-peaked curves.

Another interpretation is the hypothesis that the improvement of life conditions for a species during certain periods may result in an increased production of auxospores. A consequence of this would be a numerical predominance of the large cells (»Erstlingszellen» of German authors) in certain levels of the sediment.

Both theories are equally legitimate and only culture experiments may lead to a decision. No morphological differences between large and small forms could be noticed. As *Coscinodiscus nodulifer* is an exceptionally clearly defined species in the present material (and even for other reasons), the auxospore hypothesis is more probable than its alternative.

The essential point is — and in this regard both hypotheses agree — that the periodic appearance of large individuals in the bottom samples reflects a process which takes place in the biocoenosis of the plankton. Alterations occur in the biosphere which improve the life conditions for some or for all forms of plankton, and *C. nodulifer* reacts with an increased formation of auxospores (or with a greater development of a form so far suppressed), with the result of typical maxima of large forms in the frequency curves. It has been previously assumed that improved life conditions account for the size increase of plankton organisms. More recently *e. g.* HART (1937, p. 444) refers to the connection between the size of individuals, or even species and the content of nutrients: »It seems to me very significant, however, that all the localities where large diatom species have been recorded from the tropics are near known centres of upwelling and consequently high nutrient ion concentration. ... Recent work by PETERS (1932) has shown that *Ceratia* reach their size maxima in these areas.»[1])

Connection between Coscinodiscus-maxima and geological periods. In a given core (and consequently also in time) the maxima of large forms coincide with certain changes in the physico-chemical properties of this core zone. ARRHENIUS (1952) was able to trace a well co-ordinated rhythm between a series of physico-chemical factors, the behaviour of foraminifera and size variation of *Coscinodiscus nodulifer*. After thorough studies he arrives

[1]) cf. also WINPENNY's (1936) investigations on *Rhizosolenia styliformis*.

at the conclusion that these rhytmical fluctuations occurring in geological ages depend on a change in the circulation of the equatorial current system in the Pacific, they are coordinated with the rhythm of glacial periods and are causally connected with them. This relation may be summarized as follows: at the beginning of glacial periods the undercurrent of cold water, rich in nutrients, increases as well as the atmospheric circulation. Both these circumstances bring about an intensification of the complicated equatorial current system (see ARRHENIUS 1952. 1.1.3.1.), which acts like a rotating current cylinder. On account of the increase of circulation of this system, deep water layers also get involved in the circulation and bring deep water, rich in nutrients to the upper euphotic water layers with the important result that *life conditions for phytoplankton are improved.*

With the help of the radiocarbon-titanium method ARRHENIUS (1. c.) was further able to establish an absolute time scale. We refer to the summary of ARRHENIUS (1952. 3.4.) and especially to his Fig. 3.4.2.

The diagram fig. 7 is taken from ARRHENIUS' above mentioned work; it gives an idea of the distribution of different sizes of *Coscinodiscus nodulifer* in Core 60. The diagram represents:

the ordinates = sediment depth in cm from the surface of the bottom sample

the abscissae = the diameter of *Coscinodiscus*- valves in μ.

The diagram is an isoplethic space diagram and indicates the »heights» through density of shades, every shade corresponding to the frequency of a given size range of *C. nodulifer;* the small figures indicate the frequency of this size range in percentage of the total sum of *Coscinodiscus*

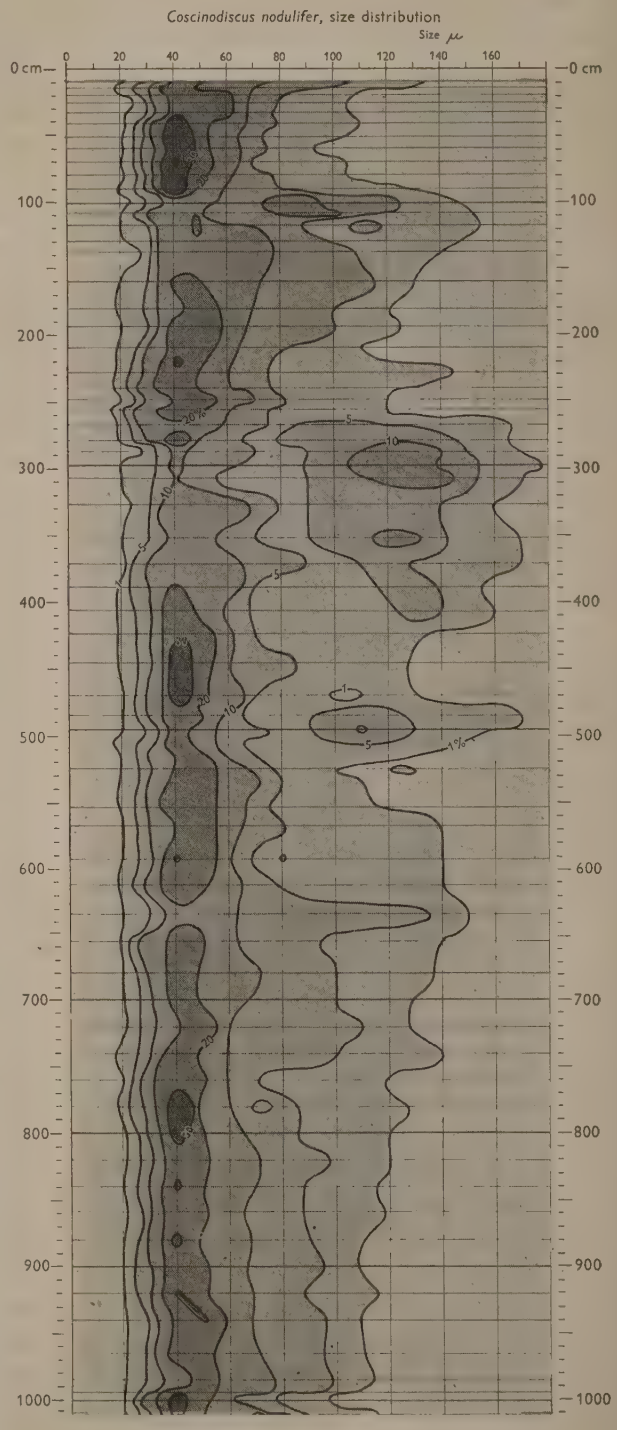


Fig. 7. (After G. ARRHENIUS 1952)

valves in a given sediment layer. For further explanation cf. ARRHENIUS (1952, 1.0.3.).

This diagram covering a depth of the sediment from 0 to more than 10 m, shows a pronounced maximum of large forms between 250 and 350 cm sediment depth; a smaller maximum is located at about 100 cm and other, secondary, less marked maxima at 500 and 630 cm. All maxima — as stated above — are formed during glacial periods: the first maximum (at 100 cm) during the Wisconsin (= »Würm») glacial period, the second (250 —350 cm) during the Illinoian (= »Riss») glacial period, and so forth.

The diagram also gives an idea of the very low rate of deposition; the rate of sedimentation or »accumulation» varies in different areas of the Pacific and in different levels of the sediment and lies between the limits of 0.29 and 8.0 cm in 1,000 years. (cf. ARRHENIUS, 1952, 1.2.10.).

In Core 60 the total rate of accumulation (»rac» according to ARRHENIUS) varied between a maximum (at 150 cm depth of sediment) of 6.5 cm wet sediment in 1,000 years and a minimum (at 517 cm) of 0.54 cm in 1,000 years (ARRHENIUS 1952, 2.60.2).

5. Size variation of Hemidiscus cuneiformis

This species belongs to the more frequent planktonic forms with a wide distribution prevalent in warm seas. In the present bottom samples *Hemidiscus* is one of the most constant and abundant forms; it is present in 86 per cent of the cores and in almost all of their levels. Its size varies within considerable limits, in our material, however, the small and the average forms are dominant. Only in Core 61 (viz. between the levels 746 and 766 cm) appears — one might say explosively — a strongly marked maximum. The form becomes numerically dominant and most individuals are exceptionally large (the largest measured specimen being 312 μ long). Only in the very limited zone of 20 cm of a single core, which corresponds to a period of about 40,000 years, these large forms were observed. This behaviour cannot be compared with the more regular rhythmical size fluctuations of *C. nodulifer* and it is impossible at present to find an explanation for it.

6. Ecological Remarks

The character of the material excludes ecological observations in a strict sense. But, when the constant occurrence of *C. nodulifer* in the whole Equatorial Pacific is compared with the relative scarcity of this species in higher latitudes, it appears that the species is exclusively planktonic and prefers warmer seas. This theory, undoubtedly, is shared by most of today's diatomists. HEIDEN (HEIDEN & KOLBE 1927) however, mentions the species from three localities between Kerguelen and the Antarctic, unfortunately without records of its frequency. PAVILLARD (1926)remarks: »Coscinodiscus nodulifer . . . d'après FORTI (1922) » . . . cette espèce absolument benthonique», mais elle a été plusieurs fois rencontrée dans d'authentiques récoltes pélagiques de l'Atlantique tropical et équatorial, de la mer d'Arabie, de l'Océan Indien. En Méditerranée détroit de Messine, mer Tyrrhéenne.» HENDEY (1927) presumes that the form is meroplanktonic, probably because he only met it at in-shore localities, and HUSTEDT (1927) asks: »Ob vorwiegend litoral?»

I think that these doubts and contradictions are due to the fact that until quite recently the records of *Coscinodiscus nodulifer* were too insufficient to give a clear picture of its biologic character. LOHMAN's (1941) regular finds of *C. nodulifer* in the Mid-Atlantic and the constant occurrence of this form in the enormous off-shore areas of the Equatorial Pacific show that *C. nodulifer* is very probably a typical euplanktonic form.

The assumption that *Coscinodiscus nodulifer* is also a species belonging to warmer seas is

TABLE 2.

1. Sum of all diatomiferous cores —22.

2. Sum of all examined levels —126.

Core No.	38	39	40	41	42	43	44	45	46	47	58	59	60	61	62	74	75	76	91	93	95	96	97	98	105	107	Percentage 1.	2.
Coscinodiscus nodulifer	5	5	5	1	1	1		1	1	3	12	15	11	11	8	12	4	6		3			2	4	4	3	100	92
Fragments	5	4	5	1	1			1	1		9	13	8	11	8	10	4	9		3			1	1	4	3	91	84
Nitzschia marina	3	4	2	1	1			1		2	8	14	11	11	8	12	4	13		3			2	3	1	2	91	84
Hemidiscus cuneiformis	3	2	1	1	1			1		2	8	13	9	11	8	12	4	12		2				1	4	1	86	76
Thalassiothrix & Th. nema	3	4	4	1						1	2	11	10	10	7	10	4	14					1	2	3	2	77	71
Asteromphalus elegans	3	4	3		1						6	15	10	11	8	11	4	1									55	61
Coscinodiscus lineatus		1	1	1	1							9	5	11	8	8	3	13		2					1		59	51
Asteromphalus hiltonianus	1	1									1	15	8	11	8	12	4	1		2							50	51
Coscinodisc. excentricus	2	2	1	1	1			1		1		7	7	3	7	6	2	6		1			2		1		77	46
Coscinodisc. africanus	3	3	1	1							1	10	10	7	3	6		2		2					1		59	40
Pseudoeunotia doliolus	2	2	4	1						1	1	9	6	7	7	5	2									1	59	38
Act. cycl. ellipt. v. elongatus	1	2	1	1							1	7	2	6	7	5	1	5									54	29
Tricerat. cinnamomeum	1		2	1	1					1	1	2	4	4	4	2	1	10						1			59	27
Actinoptychus undulatus	4	1	2	1								5	3	5	1	1	1	7									55	26
Rhizosolenia (3 spec.)	1									1	5	3		4	5	6	3	1							2		46	25
Roperia tesselata	1	1	1	1							2	4	1	2	4	9	3		1						2		59	23
Thalassiosira decipiens	1	1	1									3	4	5	6	4	1								1		45	21
Act. cycl. ellipticus (typ.)	1	1						1			1	2	5	3		2	1	9									45	21
Asterolampra marylandica	1	1	2									1	1	3	2	2		12									41	20
Coscinodisc. concinnus	1	1										3	1	6	2	3		1									36	13
Coscinodisc. paleaceus																		11									4	9
Coscinodisc. curvatulus																		10									4	8
Act. cycl. ehrenb. var. tenellus																	1	8		1							14	8
Cyclotella stylorum	1		1	1								4			2					1							27	8
Denticula nicobarica																		9									4	7
Cosc. lineatus var. ellipticus										3					3	1	2										18	7
Coscinodisc. plicatus																		9									4	7
Craspedodisc. coscinodiscus												1	1					7									14	7
Act. cycl. ellipt. v. moronensis																		7									4	6
Act. cycl. subtilis			1	1							1							4									18	6
Coscinodisc. gigas																		6									4	5
Asterolampra decora																		6									4	5
Asterolampra moronensis																		6									4	5
Coscinodisc. tuberculatus																		5									4	4
Asterolampra arrhenii																		3									4	2
Bruniopsis mirabilis																		2									4	2
Radiopalma dichotoma																		1									4	1

proved if we compare former observations, LOHMAN's results (l.c.) and those of the present work: the species has a wider area and is far more abundant in the Equatorial Pacific than in the North Atlantic.

7. Distribution of Characteristic Species in the Bottom Sediments of the Equatorial Pacific

The definition »characteristic species» includes species which are either conspicuous on account of their abundance or their constancy in the present sediment or — without being frequent — remarkable in an ecological or some other respect.

Table 2 illustrates their distribution in the bottom samples.

It should be pointed out with regard to this table that the exact counting of the quantity of recorded individuals would have been a hopeless task — the results of such an investigation being quite out of proportion to the time employed. A simpler method was therefore used, not claiming exactitude but still giving

some idea of the distribution of species and the constancy of their appearance. From each core samples were taken, with uniform intervals, from 10 to 20 levels; the presence or absence of each species concerned in the respective samples were recorded. The figures in the vertical columns, below the core numbers, indicate the number of levels (in the core concerned) in which the form was found — without considering its frequency. The vertical column (1) shows the number of cores, the last column (2) the number of samples in which the species was found, both figures expressed in percentages of the sum total of the cores viz. levels (126). From Column 1 we may deduce the horizontal distribution of species within the region studied, from Column 2, the abundance of each species in the entire material, independent of its horizontal distribution. It should be emphasized that the figures of Column 2 in particular also correspond to the general impression as regards the frequency of a form throughout the material.

Picking out of Column 2 those forms which appear in more than 40 per cent of the samples, it appears that there are mainly 10 species characterizing the diatom population of the bottom samples with regard to frequency and constancy, resulting in a sort of »floral inventory» of a thanatocoenosis.

It would be extremely interesting to compare in how much the »floral inventory» of bottom samples of other oceans differs from that of the Equatorial Pacific.

The only work making such a comparison possible is the modern survey of bottom samples of the North Atlantic by LOHMAN (1941). The author tabulates the appearance and frequency of 51 diatoms in nine cores with a total of 38 levels. If LOHMAN's values are converted in the same way as in Column 2 of Table 2 (p.14)[1]) the figures from both oceans are fairly comparable.

These figures give us a hint as to the constancy of species in the regions examined; if we restrict ourselves to the most frequent species, we find that in most cases also the abundance of the species will be expressed. A comparison of figures of the most common species of the North Atlantic (LOHMAN 1941) with those of Column 2 of our Table 2, results in Table 3.

TABLE 3.

North Atlantic

Frequent species:	Percentage of all levels:
Melosira sulcata	71 %
Thalassiothrix	71 %
Coscinodiscus radiatus	66 %
Coscinodiscus excentricus	61 %
Coscinodiscus lineatus	61 %
Coscinodiscus oculus iridis	55 %
Coscinodiscus marginatus	53 %
Endictya robusta	45 %

Equatorial Pacific

Coscinodiscus nodulifer	92 %
Fragments	84 %
Nitzschia marina	84 %
Hemidiscus cuneiformis	76 %
Thal. thrix & Thal. nema	71 %
Asteromphalus elegans	61 %
Coscinodiscus lineatus	51 %
Asteromphalus hiltonianus	51 %
Coscinodiscus excentricus	46 %

Only three species, *Thalassiothrix* + *Thalassionema*, *Coscinodiscus lineatus* and *Cosc. excentricus*, belong to the constant or frequent forms of the two regions present in 45 and more per cent of all levels. This supplies an additional proof of the cosmopolitan distribution of the species mentioned.

With regard to the other forms one may be tempted to various speculations as to their claims of temperature and, in connection with this, richness of nutrient ions of its biotope. LOHMAN (l.c.) distinguished between the species of warm, temperate, and cold waters, and by this threefold division, he drew far-reaching conclusions. I consider these attempts to

[1]) The number of levels in which a given form is present (independent of frequency factors in each level) is expressed in percentages of the sum total of the levels examined.

arrange diatoms (especially planktonic diatoms of warm and temperate seas) with some hesitation; it seems to me that the statistic material available is too insufficient to allow us to refer most species to temperature facies. With these limitations the above comparison may still be of use for conclusions as to the ecology of single forms. For instance, the dominance of *Melosira sulcata* in the North Atlantic (and its great scarcity in the Equatorial Pacific) may indicate its belonging to a cold-water facies; on the other hand, the dominance of *Coscinodiscus nodulifer* emphasizes its warm-water character. Similarly, the abundance in the Equatorial Pacific of *Ethmodiscus* (»fragments»), *Nitzschia marina*, *Hemidiscus cuneiformis*, and *Asteromphalus* may clearly show that these are warm-water species. Many of these assumptions have been made earlier. The above discussion may perhaps be regarded as a confirmation.

8. Benthonic Species

Besides the planktonic diatoms to which belong all species so far discussed, we find in the list a number of species which are partly typical mud-dwellers, partly epiphytic species, their biotope being the Littoral. To these, for instance, belong the following species, varieties, and forms:

Campylodiscus grevillei (W. Sm.) Grun. Locality: 93/198.

Cocconeis dirupta var. *sparsipunctata* (Breb.) Cl. Locality: 39/188, 39/317.

Diploneis crabro Ehr. Locality: 39/322, 39/461, 38/60.

Diploneis suborbicularis (Greg.) Cl. Locality: 40/190.

Gephyria media var. *ornata* (Grun.) Fricke. Locality: 76/23.

Glyphodesmis williamsonii (W. Sm.) Gr. Locality: 76/121.

Glyphodesmis williamsonii f. *inflata* Locality: 38/120.

Navicula approximata Grev. Locality: 39/186.

Navicula lyra var. *ehrenbergii* Cl. Locality: 40/150.

Navicula spectabilis var. *angelorum* Cl. Locality: 39/291.

Opephora pacifica (Grun.) Petit. Locality: 38/100.

Plagiogramma pulchellum Grev. Locality: 39/461.

Plagiogramma staurophorum var. *robustum* (Brun.) Hust. Locality: 39/2.

Stictodiscus buryanus var. *gracilis* Tr. & Witt Locality: 38/20, 40/350.

Stictodiscus johnsonianus f. *trigona* Tr. & Witt, Locality: 38/40.

Stictodiscus parallelus (Ehr.) Grove & St. Locality: 38/20, 39/400.

Synedra crystallina (Ag.) Ktz. Locality: 40/190.

Triceratium antediluvianum (Ehr.) Gr. Locality: 39/186.

Triceratium balearicum f. *biquadrata* (Jan.) Hust. Locality: 39/186.

Apart from these, some other (not so pronouncedly benthonic) species are recorded in the special section of the present work. It is very characteristic that most species, 16 out of the above 19, are restricted to a relatively small area of the Pacific, namely to Cores 38, 39, and 40. These cores were taken at points around the Galapagos Islands. These records of benthonic forms are, no doubt, to be attributed to the proximity of land with a considerable shore area.

This observation may lead to another conclusion. In a previous paragraph (page 8) the question of a horizontal transport of the sinking diatom valves by ocean currents etc. was discussed. It was pointed out that the distances covered by diatoms before they reach the sea-bottom are completely unknown. In this special case, it seems that these distances are, relatively speaking, not very great. Naturally the reason for this may be that the present localities were previously covered by shallow water, that the sediments have later been

further submerged to greater depths and that the species are thus autochthonous. Unfortunately, the cores from the Western Pacific are excessively poor in diatoms and no comparison with the inshore districts of this part of the Pacific could therefore be made.

In some of the cores (usually, though not always, in their lower parts) species are found which must be regarded as Pre-Quaternary and extinct; some of these have been listed in Table 2, the others will be treated in the List of Species. They generally appear sporadically and are, for the most, represented by a few specimens only. Core 76 forms an exception and will therefore be dealt with separately.

9. Core 76

This core differs from the others:

1) by the essentially different distribution of frequent and constant species in the various levels and
2) by the regular occurrence in the lower strata of this core of species lacking in other cores.

It has already been mentioned that the material studied is characterized by a relative monotony of the diatom population in *all* levels of the cores. This is not the case with Core 76.

Table 4 gives a general view of the vertical distribution of some characteristic forms in Core 76: at the left the core is marked by a double line, the figures close to it indicating the depth of the sediment in m. The vertical lines at the right hand side show the presence of each form in the respective stratum. A continuous line indicates that a species occurs in all levels down to the end of the line. A dashed line indicates that it does not appear in *all* levels of the core covered by this line.

The behaviour of the characteristic form in this material, *Coscinodiscus nodulifer* is very remarkable; its constancy in all the bottom samples and nearly all the core levels has already been emphasized. The abundance of the species in the upper layers of Core 76 is the same as in the other cores; the species dominates and is mainly represented by small individuals. Below a certain level — between 501 and 521 cm depth — the species is markedly less abundant than higher up and at a somewhat deeper level the species does not exist. The following figures will illustrate the abruptness of the appearance of *C. nodulifer* in this part of the core:

Core 76:

Levels in cm:	Number of valves of C. nodulifer per slide:
561 and all lower levels	0
541	13
521	61
501 and all higher levels	hundreds

Thalassiothrix and *Thalassionema* (which are difficult to distinguish because only short fragments exist in these samples), *Nitzschia marina* and *Coscinodiscus lineatus* are uniformly represented in all levels from 0 to more than 13 m.

Hemidiscus cuneiformis and *Triceratium cinnamomeum* are regularly present in the upper levels, but do not occur below 11 and 12 m respectively.

Actinocyclus ellipticus var. *elongatus* observed only to a depth of 4 m.

Some other forms are found in levels of 6 m and down to the deepest parts of the core; these are:

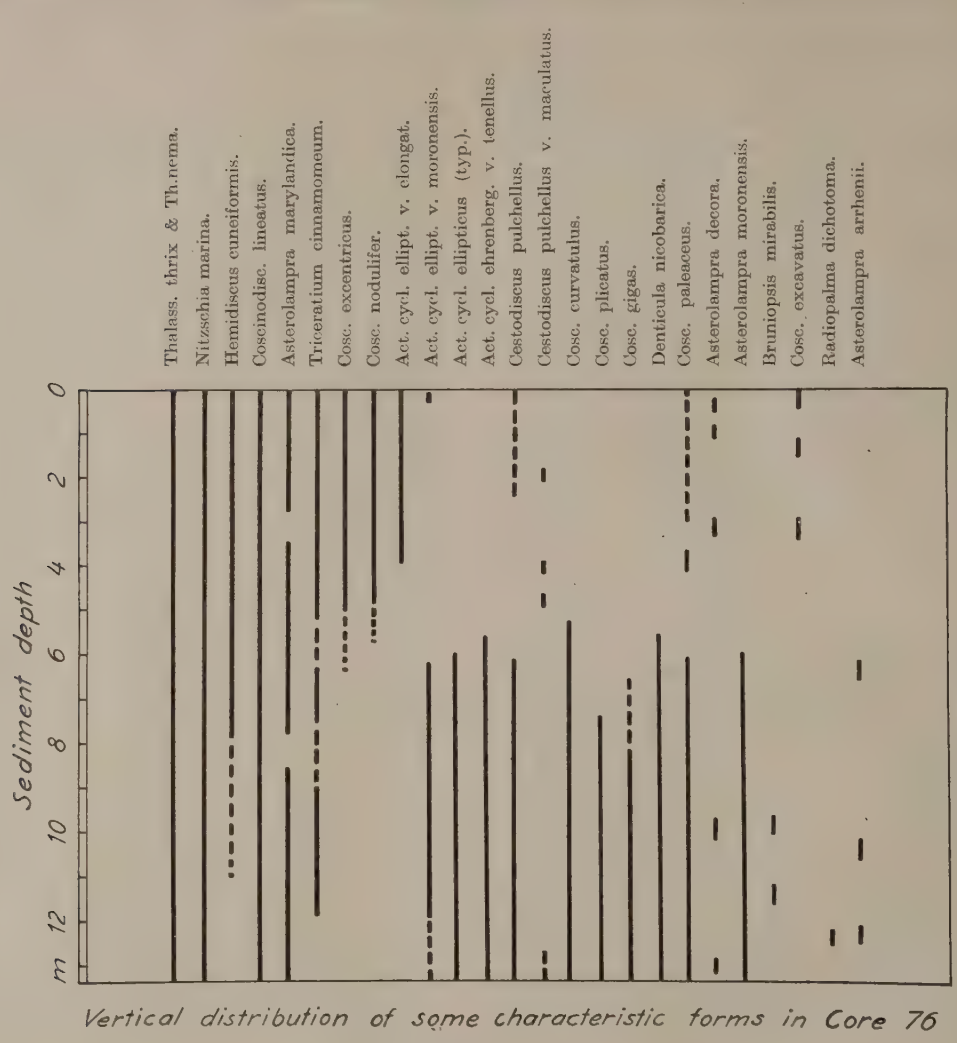
Actinocyclus ellipticus Gr. (typ.)

Actinocyclus ellipticus var. *moronensis* (Deby)

Cestodiscus pulchellus Grev. et var. *maculatus* nov. var.

Coscinodiscus curvatulus Gr. (very frequent — substitutes, so to say *C. nodulifer*, but does not show the size variation presented by this species)

Coscinodiscus plicatus Gr.



Vertical distribution of some characteristic forms in Core 76

TABLE 4.

Coscinodiscus gigas Ehr.
Denticula nicobarica Gr.
Coscinodiscus paleaceus (Gr.) Rattr.
Asterolampra moronensis Grev.
Bruniopsis mirabilis (Temp.) Karst.
Asterolampra arrhenii nov. sp
Radiopalma dichotoma Brun

Some of the above forms are species living today, but most of them claim special interest, as they are known, as far as published records go, from Tertiary deposits only, and are probably extinct. These forms will be treated below.

From a geological point of view the most essential of this vertical distribution of diatoms in Core 76 is clearly illustrated in Table 4. The change in the diatom population takes place in a quite limited zone, *viz.* in the 5—6 m zone. The stratum 5—6 m depth represents a boundary of great importance. As Pre-Quaternary species regularly appear below this zone, it is assumed *that the* 5—6 *m zone represents, in Core* 76, *the Plio-Pleistocene boundary.* This hypothesis is based on the examination of diatoms and only the results of geological studies and other micro-fossil investigations will show if it holds true.

10. Pre-Quaternary Diatoms

As regards diatoms as well as other microfossils, it is generally not easy to distinguish between Quaternary (rather: living) and Pre-Quaternary (extinct) forms. The fact that certain species are known from Tertiary localities only, by no means excludes the possibility of the same forms being still alive without yet having been observed. Nor do finds of Tertiary species in bottom samples of the deep-sea prove that these diatoms are really Recent. Also deep-sea sediments have largely been disturbed and redeposited, and the samples collected by previous expeditions (which generally only reached the upper strata of the sediments) could very well contain Pre-Quaternary forms. Only parallel studies of plankton will settle this question. Moreover, diatoms of deep-sea deposits have been examined only to a relatively small extent and there is little material for comparison.

The list in p. 18 only comprises species which often or regularly appear in Core 76. Besides these, in the same core, other species occur sporadically, *e. g. Coscinodisc. excavatus* var. *quadriocellatus*, *Cosc. punctatus* var. *rhombicus*, *Cosc. lewisianus* and *Pleurosigma nicobaricum*. Other species (probably Pre-Quaternary forms too) irregularly appearing in some other cores, will be discussed in the List of Species.

After Core 76, Core 58 contains most of the Pre-Quaternary forms. As regards the number of Tertiary diatoms (species and individuals) it is, however, inferior to Core 76.

Confining ourselves for the present to the characteristic Pre-Quaternary forms in Core 76, we find that nearly all are known from Pliocene deposits:

Actinocyclus ellipticus v. *moronensis* Deby, (Pliocene; Moron, Spain).

Asterolampra moronensis Grev. (Pliocene; Moron, Spain).

Bruniopsis mirabilis (Temp.) Karst. (Pliocene; Yeddo, Japan).

Coscinodiscus excavatus var. *quadriocellatus* Gr. (Miocene ? or Eocene ? Barbados).

Coscinodiscus plicatus Gr. (Pliocene; Nicobar Islands).

Craspedodiscus coscinodiscus Ehr. (Pliocene; Nicobar Islands, also Miocene; N. America).

Coscinodiscus paleaceus (Gr.) Rattr. (Pliocene; Nicobar Islands).

Denticula nicobarica Gr. (Pliocene; Nicobar Islands).

Radiopalma dichotoma Brun (Pliocene; Moron, Spain) and further:

(*Asterolampra arrhenii*) nov. sp.

(*Liriogramma petterssonii*) nov. sp. (2 new forms: about their age nothing can be said, but most probably they are Pre-Quaternary and extinct).

Four of the above forms are mainly (or exclusively) known from the limestone of Nankauri (Nicobar Islands). A comparison of the original material from Nankauri with the bottom levels of Core 76 shows the full identity of the forms from both localities; furthermore, both localities have in common, besides the above fossil forms, some other, recent forms (see the List of Species).

In spite of the ecological diversity of the material (the Nankauri limestone contains many benthonic forms and was probably deposited in relatively shallow water) there certainly is a similarity between the two occurrences in the *limestone from Nankauri and in the lower strata of Core 76 from the Equatorial Pacific*, pointing to a similarity in age.

11. List of Species

Contrary to the custom in Europe, which is to enumerate forms in a taxonomical order, species and genera have been arranged alphabetically in this paper. Following the example of American authors, this procedure seems to the writer to be most appropriate (except where purely taxonomic works are concerned):

it saves the usual index and the reference is greatly facilitated. Moreover, the reader being generally an expert himself, is undoubtedly well acquainted with the taxonomical position of the genera.

The localities are usually given by 2 numbers, the first representing the number of the Core and the second the sediment depth in cm.

Generally, complete citations of synonyms and illustrations are not aimed at. Only those diagnoses and illustrations which, in the authors opinion, were the best, are cited; however, completeness was as much as possible aspired to in some of the taxonomic-critical discussions.

The International Rules of Botanical Nomenclature unfortunately still insist on Latin diagnoses for recent new species; in accordance with the Rules, Latin diagnoses are summed up at the end of this section.

Actinocyclus Ehr.

Actinocyclus ehrenbergii Ralfs.

VAN HEURCK 1881, Pl. 123, fig. 7.

PERAGALLO 1908, Pl. 114, fig. 1, 2.

HUSTEDT 1927, I, p. 525, fig. 298.

The typical form is extremely rare in the material.

Very scarce in Core 58/140 and 58/190.

Actinocyclus ehrenbergii var. *crassus* (W. Sm.) Hust.

VAN HEURCK 1881, Pl. 124, fig. 6, 8.

PERAGALLO 1908, Pl. 114, fig. 3, 4.

HUSTEDT 1927, I, p. 530, fig. 301.

A few individuals observed in Cores 58 and 76 only.

Actinocyclus ehrenbergii var. *tenellus* (Breb.) Hust.

PERAGALLO 1908 Pl. 113; fig. 7.

HUSTEDT 1927 I, p. 530, fig. 302.

This form appears in the present material with a very characteristic fasciculate structure, which is constant and does not vary; transitions to the typical form mentioned by HUSTEDT (l. c.) do not occur in the present material.

Localities: Core 75 (rare), 76 (in many levels and fairly frequent), 93 (rare).

Actinocyclus ellipticus Gr.

Synonyms: *Cestodiscus ovalis* Witt, WITT 1885 Pl. 8, f. 11.

VAN HEURCK 1881 Pl. 124, fig. 10.

PERAGALLO 1908 Pl. 114, fig. 8.

HUSTEDT 1927, I, p. 533, fig. 303.

Icon nostr. Pl. III fig. 26.

The group of *Actinocyclus ellipticus*, especially its varieties, belongs to the very characteristic diatoms of the Equatorial Pacific. The typical form is not frequent but spread in many cores.

Localities: Cores 38, 39, 45, 58, 59, 60, 61, 74, 75, 76 (frequently found in most levels).

The species shows a strong inclination for variations of the valve shape and structure: the valves become longer, more slender and more hyaline; the areolae become so delicate that they can hardly be identified with a dry objective. By very frequent transitions (among these also lanceolate forms)[1]) the species passes over into the variety here below, often illustrated but not identified with certainty.

Actinocyclus ellipticus var. *elongatus* (Grun.) nov. comb.

Icon nostr. Pl. III, fig. 28, 31 (ocellus).

Synonyms: *Actinocyclus*? *elongatus* Grun. in V. H. Syn. Pl. 125 f. 15

Actynocycl. ? *elongatus* var. *dubia* Gr., ibid. fig. 17.

Coscinodiscus (?) *elongatus* Gr., ibid. fig. 14.

Willemoësia sp. Castr. CASTRACANE 1886,p. 165, Pl. 8 fig. 8 a, 8 b.

Stoschia punctata Grove & Sturt, GROVE & STURT 1886, Pl. 14, f. 52.

Coscinodiscus humilis Rattr. RATTRAY 1890, p. 4.

The uncertainty of early authors regarding this form is accounted for by the fact that the ocellus could not be identified with the optical instruments of their time. It is small, but sharply defined and in our material, in all

[1]) f. lanceolata nov. f. Icon nostr. Pl. III, fig. 27.

specimens (many hundreds), it could be identified with certainty. GRUNOW (VAN HEURCK 1880) however notes: »aux extremités de la valve un point plus marqué que les autres», which may depend on an error of observation, as the ocellus always lies close to the middle of one of the long sides of the valve. CASTRACANE (1. c.) illustrates *Willemoësia* sp. in his drawing, Pl. 8, f. 8 with distinct ocelli (probably it was the question of a frustule, as he figures two »eyes»), but he does not come to a final conclusion as to whether his form belongs to *Actinocyclus*.

Having observed 3 ocelli in one of his 3 (!) specimens, MANN (1925, p. 175) disputes that *Willemoësia* belongs to the genus *Actinocyclus*. Further, 1937, p. 80, Pl. 6, f. 10, he describes a *Willemoësia elongata* sp. nov. which in structure and habit has nothing to do with a *Willemoësia*. In spite of his giving it a name, MANN has doubts and thinks that his form may be an *Eucampia* which is probably right.

In our material a considerable variation range of the form was observed; besides small (rarely found), very long samples (up to 191 μ at a breadth of 29 μ) were found frequently. As earlier observers have already pointed out the form has a tendency to develop asymmetric ends and at times it also shows a slight median constriction.

As far as distribution and frequency are concerned *Actinocyclus ellipticus* var. *elongatus* belongs to the characteristic forms of the area.

Localities: Cores 38, 39, 40, 58, 59, 60, 61, 62, 74, 75, 76.

Actinocyclus ellipticus var. *moronensis* (Deby) nov. comb.

Icon nostr. Pl. III, fig. 29, 30

Synonyms: *Actinocyclus moronensis* Deby RATTRAY 1890 a, p. 195.

Cestodiscus moronensis J. Br. BRUN 1891, p. 6, Pl. 6, fig. 4.

The form, well illustrated by BRUN (1. c.), is restricted in our material to Core 76 in which it appears from a sediment depth of 602 cm down to the lower end of the core (one single specimen, however, was found in an upper layer). The form definitely belongs to the group *Actinocyclus ellipticus;* intermediate forms between var. *moronensis* — var. *elongatus* — forma *typica* were fairly frequent in our material. Our typical specimens fully agree with RATTRAY's (1. c.) diagnosis as well as with the individuals from the original material from Moron.

Localities: Core 76/23 (one sample), 76/602 and from this level on to 76/1161 frequent, from 76/1221 to the end of the core rare to very rare.

The localities so far known, of the group *Actinocyclus ellipticus* (including the typical form?) seem to indicate that this group belongs to the Pliocene forms which are probably extinct today. According to our present knowledge the finds in deep-sea sediments (CASTRACANE and MANN 1. c.) are no proof of the recent existence of a form.

Actinocyclus subtilis (Greg.) Ralfs

RATTRAY 1890 p. 188.

PERAGALLO 1908, Pl. 114, fig. 5, 6.

HUSTEDT 1927, I, p. 534.

The individuals observed were rather untypical: the areolation was in general somewhat coarser than called for by the diagnosis and the ocellus obviously small. But typical specimens were also found, although rarely.

Localities: Cores 39/317, 40/350, 58/321 and 76 (here in many levels down to a sediment depth of 700 cm).

Actinoptychus Ehr.

The genus *Actinoptychus* is represented in the material only by one species:

Actinoptychus undulatus (Bail.) Ralfs.

HUSTEDT 1927, 1, p. 475.

Almost exclusively small individuals with an average diameter of 30 μ; with the exception of some specimens with a diameter of up to 80 μ. Throughout the material but not frequent.

Localities: Cores 38, 39, 40, 41, 59, 60, 61, 62, 74, 75, 76, 98.

Asterolampra Ehr.

In addition to the characteristic species enumerated below, the material (especially Core 76) contained several forms which could not be determined because of their intermediate, inconstant and rather vague character. There is no idea in naming these forms until an urgently needed critical modern revision of the genus has been made.

Asterolampra arrhenii nov. sp.

Icon nostr. Fig. 8 and Pl. 1V, fig. 43.

Cells reniform with flat valves, long axis 138 to 210 μ, short axis 84—150 μ. Diameter of the central space about 1/4 of the long axis. The central area contains 8 to 14 sectors which are separated from each other by rectilinear, unbroken and sometimes forked lines.[1])

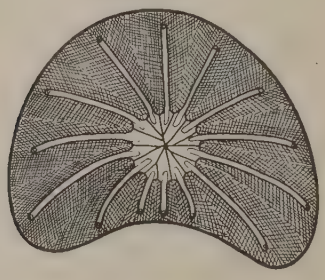


Fig. 8. *Asterolampra arrhenii* nov. sp.
The striation of the figure is exaggeratingly coarse.

On the outside of the central space: 8 to 14 curved rays,[2]) which are more curved in the direction of the long axis and less or not at all in the direction of the short axis; the rays are narrow (about 3 μ), of unequal length due to the shape of the valve; they do not reach the border and end in a small terminal pore (spine?) each.

The irregular sectors[3]) (properly speaking: trapezoids) included between the rays are rather coarsely areolate (about 12 areolae in 10 μ). In each trapezoid the rows of areolae run parallel to the rays and are crossed by oblique lines at an angle of about 60° to their axis; the areolation shows a faint median line at the place where the 2 systems of parallel rows of areolae meet each other. The type of areolation is strictly similar to the areolation of e. g. *Asterolampra Grevillei*.

Dedicated to Dr. G. Arrhenius, the geologist of the Swedish Deep-Sea Expedition.

This large peculiar and apparently delicate form had for the most been observed in fragments; as it was by no means rare at its localities, some undamaged valves were found and photographed.

Locality: only a few deeper levels of Core 76: 76/541, 76/1061, 76/1101.

Strange to say, this large and conspicuous form has, as far as I know, not been observed hitherto. It is found only in the deep levels of Core 76, which contains most of the Tertiary forms of the material; it may be inferred, that this form also belongs to the Pre-Quaternary extinct forms as do most species of this genus.

Asterolampra decora Grev. (nec *decorata* Grev.)

Greville 1862, p. 45, Pl. 7, fig. 4—6.

A. S. Atl. Pl. 137, fig. 7 (misnamed as *A. decorata*).

Castracane 1886, Pl. 16, fig. 9.

Rattray 1890, p. 202.

de Toni 1891 p. 1409.

This species with its characteristic central rosette is rather frequent throughout the whole of Core 76. The development of the central rosette varied between 4 single »central areolae» and a complex of up to 24 such »central areolae» disposed in 2 concentric circles. Under high magnification the surface of the central areolae appeared minutely dotted.

In my opinion it is impossible to separate *Asterolampra affinis* Grev. (Greville 1862, Pl. 7, fig. 9) from the present form.

Hitherto known from Tertiary localities only: Barbados and Oamaru.

Locality: only Core 76—76/23, 76/41, 76/321, 76/981 and 76/1301.

Asterolampra grevillei (Wall.) Grev.

Hustedt 1927 I, 489.

[1]) »rays» according to Rattray 1890.
[2]) »intervals» according to Rattray 1890.
[3]) »compartments» according to Rattray 1890.

RATTRAY 1890 p. 196.

Localities: Core 58/765, but especially Core 76—76/23, 76/41, 76/281, 76/841, 76/1261, 76/1301.

Asterolampra marylandica Ehr.

A. S. Atl. Pl. 137, fig. 19,20.

HUSTEDT 1927, I, p. 485.

Localities: generally dispersed and not frequent in the material; frequent and constant in most levels of Core 76.

Asterolampra moronensis Grev.

A. S. Atl. Pl. 38, fig. 24.

Icon nostr. Pl. I, fig. 3.

Synonyms: *Asteromphalus moronensis* Rattr. (RATTRAY 1890 p. 211). *Asteromphalus dubius* Hanna & Grant (HANNA & GRANT 1926, p. 126 Pl. 13, fig. 2).

Described by GREVILLE (l. c.) as *Asterolampra* it was transferred by RATTRAY (l. c.) to *Asteromphalus* because of its asymmetric ray. HANNA & GRANT (l. c.) »rechristened» and placed it under *Asteromphalus* for the same reason as RATTRAY. The asymmetric ray (and its central sector) is a very unreliable character with regard to this species and the same also applies to some other species of the genus; in our material there are forms fluctuating between the two genera: *Asteromphalus* and *Asterolampra*.

As far as I know, hitherto found only in Tertiary deposits from Moron and Santa Monica.

Locality: deep levels in Core 76 only.

Asteromphalus Ehr.

As with *Asterolampra*, there are forms of *Asteromphalus* in our material which are difficult to connect with known species, although the deviations do not justify the creation of new varieties. A revision of this genus is very necessary. Two representatives of this genus, *Asteromphalus elegans* and *Asteromphalus hiltonianus*, belong to the frequent and characteristic forms of the area.

Asteromphalus arachne (Breb.) Ralfs.

HUSTEDT 1927, I, p. 493.

This very typical form occurs frequently in the upper levels of Core 38; rarely in Cores 39, 40 and 76.

Asteromphalus diminutus Mann.

MANN 1937, p. 25, Pl. 2, fig. 3—4.

Localities: Cores 38/160, 62/490.

Asteromphalus emergens Mann.

MANN 1937, p. 25, Pl. 2, fig. 5.

The specimens observed do not agree with MANN's diagnosis inasmuch as the rays do not reach the border.

Locality: Core 76/297.

Asteromphalus elegans Grev.

GREVILLE 1860, p. 119, Pl. 4, fig. 16.

A. S. Atl. Pl. 38, fig. 1, 2.

RATTRAY 1890, p. 212.

Asteromphalus elegans belongs to the leading forms of the bottom samples of the Equatorial Pacific. It appears for the first time and rather frequently at its eastern part, reaches its highest development in the bottom samples from Core 59 to Core 74[1]) and is still found in Cores 75 and 76. In the Equatorial West Pacific it is completely absent, but this may be due to the nature of the localities where only few strongly corroded diatoms were found (cf. General Section: Resistance to corrosion).

Localities: Cores 38, 39, 40, 42, 58, 59, 60, 61, 62, 74, 75, 76.

Asteromphalus heptactis (Breb.) Ralfs.

A. S. Atl. Pl. 38, fig. 5, 6.

RATTRAY 1890, p. 216.

HUSTEDT 1927, p. 494.

Only 1 locality (a few specimens): 39/155.

Asteromphalus hiltonianus (Grev.) Ralfs.

GREVILLE 1860, p. 117, Pl. 4, fig. 15.

RATTRAY 1890, p. 213.

Distribution and frequency are very similar to *A. elegans*, usually occuring in our material together with this form. Found rarely in the eastern Pacific and also reaching its highest development in the bottom samples from Core 59 to Core 74.

[1]) giant specimens (diameter up to 186 μ) were observed in Core 74.

Localities: Cores 38, 39, 58, 59, 60, 61, 62, 74, 75, 76, 93.

Asteromphalus roperianus Ralfs.

Greville 1860, p. 120, Pl. 4, fig. 14.

A. S. Atl. Pl. 38, fig. 15.

Rattray, 1890, p. 209.

Localities: rare in Cores 40/350, 59/120, 59/140, 61/100, 61/220.

Auliscus Ehr.

Auliscus caelatus var. *rhipis* (A. Schm.) Perag.

A. S. Atl. Pl. 32, fig. 12.

Peragallo 1908, p. 401, Pl. 109, fig. 3.

Hustedt 1927, I, p. 520.

Only 1 specimen in Core 38/160.

Biddulphia Gray

Biddulphia pulchella Gray.

A. S. Atl. Pl. 118, fig. 26—33.

Hustedt 1927, I, p. 832.

Some few specimens of this typical benthonic form in Core 39/186.

Bruniopsis Karst. (= Brunia Temp.)

Karsten (1928) changed the generic name established by Tempere (1890, p. 21) from *Brunia* to *Bruniopsis*, without giving a reason for his proceeding.

As Linné 1753 established a valid Angiosperm-genus *Brunia*, it was necessary according to the International Rules of Bot. Nomenclature to change Tempere's name of this genus which probably explains Karsten's action.

Bruniopsis mirabilis (Brun) Karst.

Brun 1889, p. 27, Pl. 8, fig. 1.

Icon nostr. Pl. IV, fig. 44 a, 44 b.

In two deep layers of Core 76, a number of fragments of this peculiar form, known from the limestone from Yeddo (Japan, Pliocene) and Churchill Hill (N.-America, Miocene?) were found. Brun observed this very large and delicate species (probably reaching a diameter far exceeding 1 000 μ) in his material in fragments only. Our material also presented more or less large fragments only of the characteristic disc margin. Its structure with the typical so-called »large cells» or »loculi» (see our figure and Brun's illustration) is so characteristic as to have no doubt as to the species. This form is undoubtedly extinct and its presence in Core 76 is of great interest.

Localities: Core 76/1001 and 76/1061.

Campylodiscus Grun.

Campylodiscus grevillei (W. Sm.) Grun.

V. Heurck 1880, Pl. 28, fig. 8—12.

Hustedt 1927, I, p. 321.

A few single individuals of this typical benthonic form were found only at a few localities near the Galapagos Islands.

Locality: Core 39/246.

Cestodiscus Grev.

This genus has had many vicissitudes. After having been established by Greville it was emended by Castracane (1886). Rattray (1890) and de Toni (1891) included it in the genus *Coscinodiscus*. Mann (1937) pleads again for its independence for a very sound reason: although the deviations from *Coscinodiscus* are only slight, he finds however that any subdivision of this unwieldy genus is to be welcomed. I also think it desirable, so much the more, since the characters of *Cestodiscus* are very constant, at all events in our material. Mann (l. c.) speaks in favour of the genus *Cestodiscus* but, actually misinterprets it, since he refers *Coscinodiscus lewisianus* — a form of a totally different structure without the characteristic long processes — to *Cestodiscus* (!).

In the present material represented by two forms.

Cestodiscus pulchellus Grev.

Greville 1866, p. 123, Pl. 11, fig. 5.

A. S. Atl. Pl. 138, fig. 15 (probably).

Synonyms: *Cestodiscus Stokesianus* Grev. 1866, p. 123, Pl. 11, fig. 4. *Cestodiscus pulchellus* var. *trinitatis* Grun, V. H. Syn. *Cestodiscus convexus* Castr. 1886, p. 123, Pl. 7, fig. 6.

A very characteristic, strongly convex form with coarse areolation and relatively few processes, their length being about 1/4 to 1/6 of the valve-radius. Our specimens had a diameter of 54 to 84 μ, the marginal striae were very constant 10 in 10 μ; the number of processes fluctuated between 9—14, independent of the diameter of the individual.

Localities: 58/805, 76 — sporadic and dispersed in the upper layers, frequent and constant in levels from 600 cm and onwards.

Cestodiscus pulchellus var. *maculatus* var. nov.
Icon nostr. Pl. I, fig. 8.

Flat disc, diameter 47—94 μ, distinctly projecting edge about 2.5 to 3 μ broad with pronounced smooth striae, ca. 10—12 in 10 μ; areolae disposed in irregularly undulating circlets, 4.5—6 in 10 μ; processes 9—16 according to the size of the individual. Between the areolae one can see numerous spotlike formations, which at higher focus appear as dark patches. At low focus they appear distinctly as slight thickenings of the cell membrane with almost indiscernible (mucous?) pores.

A comparison of my material with the original material of Nankauri and Barbados showed that my species is identical with that found in the Polycystine limestone of Nankauri and Barbados with the exception of the spots, so characteristic of my variety. RATTRAY (1890) rejects the name *pulchellus*, as he refers the species to *Coscinodiscus*, in which genus it was already given. If the genus *Cestodiscus* is to be kept (as I suggest), RATTRAY's objection is ruled out.

Localities: exclusively Core 76 (181, 402, 461, 1301, 1321, 1341 cm).

Chaetoceros Ehr.

Of the genus *Chaetoceros*, with its many species, almost no valves reach the sea floor. The few valves and fragments which could be observed belonged characteristically enough to the species with the most massive setae. Strange to say, no resting spores at all were to be found in the present material although they are known to be thickwalled and very resistant. Does this indicate that the development of resting spores in this genus rarely occurs in the tropical belt?

Chaetoceros coarctatus Laud.
A. S. Atl. Pl. 324, fig. 8—11.
HUSTEDT 1927, I, p. 655.

At some localities only single valves belonging to terminal cells were observed, *i. e.* the valves with the strongest terminal setae, a circumstance rendering the exact determination more difficult. The extreme thickness of the terminal setae (mostly 15 μ) leaves only a choice between *Ch. pervianus* and *Ch. coarctatus;* the curve of the setae clearly speaks in favour of the latter form. The structure of the terminal setae differs however in some details from HUSTEDT's (l. c.) description of its anatomy: in my specimens the terminal setae have only small sawlike notches and no rows of double dots; they have indistinct transverse lines, like *Ch. peruvianus;* their transverse section seems to be circular, not elliptical as stated by HUSTEDT (l. c.)

Localities: 39/311, 61/705, 61/746, 75/201.

Chaetoceros messanensis Castr.
A. S. Atl. Pl. 322, fig. 4, 7.
HUSTEDT 1927, I, p. 718.

A few specimens of this species, having solid bifurcated setae were met with in some of the bottom samples, *i. e.* only in the vicinity of the Galapagos-Islands. Is this purely accidental?

Localities: 39/317, 40/190, 40/250, 40/310.

Cladogramma Ehr.

Cladogramma pacificum sp. nov.
Icon nostr. Pl. III fig. 34.

A small centric form with a peculiar valve marking was found in Core 60. Its proper taxonomic position meets with some difficulty, this peculiar structure differing from the species so far described. There is a remote resemblance to CLEVE's form *Liradiscus capensis* (CLEVE, 1881, p. 11, Pl. 5, fig. 61) but it differs from the

latter form by its radial and coarser marking, and the central area. It seems best to fit into the genus *Cladogramma;* most forms of this genus, however, have very convex domed valves, with the exception of *Cl. jordanii* Hanna (Hanna 1927, p. 16, Pl. 2, fig. 1). The valve marking has a certain similarity with *Cl. cebuense* Gr. van (Heurck 1880, Pl. 83 bis, fig. 20) from which, however, it differs by the type of bifurcation of the radii and by the central area.

Like Grunow (l. c.) who puts an interogation mark after the genus of his form, I place the present form with some reservation into the uncertain and little known genus *Cladogramma*. So much the more as only one specimen of the form was found.

Diagnosis: small centric form (diameter 21 μ) with thin valves.

Marking: from a small circular centre relatively coarse lines radiate so as to produce a stellate appearance; the radii bifurcate repeatedly at the periphery of the valve; border indistinctly striated (marginal striae 20 in 10 μ).

Locality: Core 60/447.

Lauby (1910, p. 174, Pl. 11, fig. 21) described a new form: *Cyclotella asterolampra*, which at first sight has a certain similarity with *Cladogramma pacificum*. *C. asterolampra*, however, differs in some respects considerably from the form described here:

1. contrary to *Cl. pacificum*, its valves are very convex;
2. the structure of *C. asterolampra* is quite a different one: from a small circular centre lines radiate regularly bifurcating twice; the ends of the secondary bifurcation terminate in a circlet of oblong »pearls» which join the marginal striae. — Moreover, a structure which — by the way — justifies the form being placed into the genus *Cyclotella*.
3. Lauby's form was found in a typical freshwater sediment.

Cocconeis Ehr.

Cocconeis dirupta var. *sparsipunctata* (Breb.) Cl.

Brun 1891 p. 18, Pl. 18 fig. 8.
Cleve 1894, II, p. 176.
A. S. Atl. Pl. 196, fig. 14.

This species is — like all other forms of this genus — probably epiphytic; as far as literature goes, it is hitherto known only as a fossil from Japan. In the region of the Equatorial Pacific it was found only at one locality near the Galapagos-Islands, and then only in 2 specimens.

Locality: Core 39/188, 39/317.

Coscinodiscus Ehr.

The genus *Coscinodiscus* with its almost innumerable species, justifiably feared by taxonomists, is comparatively rarely represented in our material with regard to the number of species, although one might well expect a more variegated flora in the plankton of the Equatorial Pacific.

As has already been mentioned, the corrosion during the sinking of dead individuals performs a kind of physicochemical selection, and forms with delicate cell walls do not reach the ocean floor. The corrosion hypothesis does not, however, give us a full explanation regarding differences between the diatom flora of the plankton and the »floral inventory» (see page 15) of the ocean floor. Nor does it explain how it is that many of the most delicate and small *Coscinodiscus* species occur relatively often in the sediment. Very small forms occur, whose identification is rendered more difficult, as the specific characters of these dwarfs are extremely faint and often completely obliterated. It is only when one comes across them »en masse» as *e. g. C. nodulifer* — when they present all transitions from large to small individuals — that it is possible to be sure of the species. This holds true — mutatis mutandis — for many other genera and species.

Coscinodiscus aeginensis A. Schm.

A. S. Atl. Pl. 113, fig. 13, 14.

Rattray 1890, p. 41.

Icon nostr. Pl. I, fig. 9, 10.

It is difficult to say how far the character of the species: the area with detached, round or comma-shaped papillae, is constant and entitles to establish this species. At all events the specimens, which in the present material are confined to Core 76, agree well with the cited figures in Schmidt's (l. c.) Atlas.

Hanna (1932, p. 178, Pl. 5, fig. 9) illustrates a form which can hardly be identified with *C. aeginensis* as the typical central area is missing.

Localities: 76/23, 76/1261, 76/1301.

Thanks to the kindness of Mr. A. Elger, Eutin, I received, after having finished the manuscript, original material from Aegina, Greece. The form frequently appearing in this material has indeed quite a different character than the one here discussed. It has only a »rough» similarity with the figure mentioned in A. S. Atl., nor does it exactly correspond to Rattray's (l. c.) description.

The form from the original material has throughout only a hyaline central area and lacks central apiculi or processes, as shown in A. S. Atl. and in my photographs (Pl. 1, fig. 9, 10). Furthermore, the »original form» has extremely thick chamber (partition) walls and most areolae are r o u n d, appearing as isolated, round areolae at a certain focus. Finally, all shortened rows of areolae terminate with distinct interstitial areolae (»Interstitialmaschen» of German authors), similar to *Coscinodiscus obscurus*. I have some doubts whether the »original» *C. aeginensis* is not actually an untypical *C. obscurus*.

Owing to these discrepancies, the determination of the present form must be considered as doubtful.

Coscinodiscus africanus Jan.

A. S. Atl. Pl. 59, fig. 24, 25.

Rattray 1890, p. 86.

Hustedt 1927, I, p. 429.

In the present material this form is widespread and occasionally very frequent. On the smallest specimens the typical marginal structure becomes indistinct; so does the furrow in the central part of the valve pointed out by Hustedt (l. c.); these specimens are difficult to distinguish from *C. tabularis* var. *egregius*.

Localities: Cores 38, 39, 40, 41, 58, 59, 60, 61, 62, 74, 76, 93, 105.

Coscinodiscus anguste-lineatus A. Schm.

A. S. Atl. Pl. 59, fig. 34.

Truan & Witt. 1888, pl. II, fig. 2.

Rattray 1890, p. 26.

Hustedt 1927, I, p. 391.

Brockmann, Chr. 1928, p. 168, Pl. 2, fig. 4.

Cleve-Euler, A. 1951, p. 61, fig. 86 a.

In my opinion *C. anguste-lineatus* is a somewhat doubtful species. The diagnoses and figures of the form are rather contradictory: the original figure in A. S. Atl. (l. c.) and the one in Truan & Witt show no hyaline border, while Rattray's (l. c.), A. Cleve's (l. c.), Brockmann's (l. c.) and Hustedt's (l. c.) diagnoses and figures mention it. The data about its areolation differ too: the number of areolae in 10 μ is given by A. S. Atl. (ex fig.) as 9, by Truan & Witt (ex fig.) as 4, by Rattray as about 6, by Brockmann (ex fig.) as 4, by Hustedt as about 5—6 and by A. Cleve as about 10. Prominent single apiculi are mentioned only by Hustedt and A. Cleve. I do not think — as I have repeatedly mentioned — that the latter character is of a sound taxonomic value, as I found such apiculi in other *Coscinodisci* usually having no such structures.

I have observed in the present material some small specimens which could not be connected either with *C. excentricus* or with *C. lineatus* although being intermediate forms between the two species, measuring from 30 to 60 μ in diameter, having an areolation of about 6—8 areolae in 10 μ, no hyaline border and no prominent apiculi. I mention them here with great reservation under the name of *C. anguste-*

lineatus and one of my objects of mentioning them is to start a discussion on this doubtful form.

Localities: Cores 38/280, 39/115, 39/510, 59/890, 74/962.

Coscinodiscus argus Ehr.

HUSTEDT 1927, I, p. 422.

This species was understood in the sense of HUSTEDT (1. c.) viz. including *C. crassus* and *C. heteroporus*.

Rare in the region of the Galapagos-Islands: perhaps a confirmation of HUSTEDT's assumption that it is a littoral species.

Localities: Core 38/60, 38/160.

Coscinodiscus concinnus W. Sm.

A. S. Atl. Pl. 114, fig. 8, 9.

PERAGALLO 1897, Pl. 115, fig. 12.

HUSTEDT 1927, I, p. 442.

Rather widespread in the Equatorial Pacific but not a frequent species. Its large size often leads one to overrate a frequency which does not exist in reality.

Localities: Cores 38, 39, 59, 60, 61, 62, 74, 76.

Coscinodiscus crenulatus Grun.

A. S. Atl. Pl. 57, fig. 38.

RATTRAY 1890, p. 41.

HUSTEDT 1927, I, p. 411.

Rather scarce in Cores 38, 39, 61.

Coscinodiscus curvatulus Grun.

A. S. Atl. Pl. 57, fig. 34.

PERAGALLO 1897, Pl. 115, fig. 8.

HUSTEDT 1927, I, p. 406.

Icon nostr. I, fig. 1.

The way this form appears in the Equatorial Pacific is rather remarkable: *C. curvatulus* frequently occurs in Core 76 only, beginning at a certain depth and replacing *C. nodulifer*, which was dominant to this depth.

Localities: only Core 76, all levels from 521 cm down to the end of the core.

Coscinodiscus curvatulus var. *odontodiscus* (Grun.) Hust.

HUSTEDT 1927, I, p. 408.

Only a few specimens strictly conform to the diagnosis; otherwise only intermediate forms passing into the typical species.

Locality: Core 76, upper levels.

Coscinodiscus curvatulus var. *minor* (Ehr.) Grun.

GRUNOW 1884, p. 31, Pl. D. fig. 8, 10.

RATTRAY 1890, p. 39.

HUSTEDT 1927, I, p. 409.

This form, frequent in the deeper levels of Core 76, does not seem to be quite clear taxonomically. In our material it is transitorially closely related to *C. tuberculatus* var. *monicae* Grun. (see below).

In spite of many intermediate forms two types are easily distinguished in our material, differing from each other merely by the character of their marginal processes. According to GREVILLE (1861) and RATTRAY (1. c.) *C. tuberculatus* is distinguished by coarser border processes as well as by a coarser areolation (cf. my statement re. *C. tuberculatus*). In Core 76, forms with weakly developed processes were therefore ascribed to *C. curvatulus* var. *minor*, the others to *C. tuberculatus*.

With a greater material to work with, taxonomists are recommended to study the relationship (possibly the synonymy) between these two species.

Localities: only Core 76, from the deeper levels of 861 cm sediment depth more frequent.

Coscinodiscus decrescens Grun.

A. S. Atl. Pl. 61, fig. 7, 8, 9.

GRUNOW 1884, p. 28.

RATTRAY 1890, p. 77.

HUSTEDT 1927, I, p. 430.

This species belongs to the rare forms in the present material; mainly in Core 76.

Localities: Cores 58/704, 58/765, 76/881, 76/922, 76/1281.

Coscinodiscus excavatus var. *quadriocellatus* Gr.

Synonym: *C. diophthalmus* CASTRACANE (1886, Pl. 16, fig. 4).

Icon nostr. Pl. I, fig. 2.

This unusual and very conspicuous form represents one of the most remarkable finds in the Equatorial Pacific.

Coscinodiscus excavatus, with its varieties belongs to the characteristic forms of Tertiary deposits from Barbados; further localities are also Tertiary diatomites from North America and Trinidad; in these, however, the form is not so frequent as in the Barbados deposits. The group is so unique that it cannot escape attention of the observer.

The first discovery of this Pre-Quaternary form by CASTRACANE (l. c.) in a bottom sample of the tropical Pacific from 2900 fathoms depth was therefore quite a sensation at that time.

The present rediscovery of the form in the Pacific (at a point not very far from CASTRACANE's locality) is today less astonishing, as there are now many finds of Pre-Quaternary extinct forms at hand in previously unexpected localities.

It is symptomatic that only two cores contained the species: 58 and 76, viz. the two cores which were the richest in Tertiary forms.

Localities: Cores 58/60, 58/659, 58/920, 76/181, 76/440.

Coscinodiscus excentricus Ehr.

A. S. Atl. Pl. 58, fig. 46—49.

VAN HEURCK 1880, Pl. 130, fig. 4, 7, 8.

HUSTEDT 1927, I, p. 388.

This cosmopolitan form is also represented in our material as a frequent constituent of all core samples. It is met with in about 3/4 of all cores, in some levels, however, not so frequently as *C. lineatus*.

Localities: rather uniformly distributed over most diatomiferous cores of the area.

Coscinodiscus gigas Ehr.

A. S. Atl. Pl. 64, fig. 1.

RATTRAY 1890, p. 93.

HUSTEDT 1927, I, p. 456.

Icon nostr. Pl. IV, fig. 45.

The presence of *Coscinodiscus gigas* in this material is — as was the case with some other forms — quite peculiar. Its presence is restricted to one Core (76) and in this core it appears only in the deeper levels, viz. from 8 m depth and below; in some layers of this core the form is comparatively frequent.

The specimens were of an average size, their diameter varying from 280 to 392 μ.

Localities: Core 76 — from a sediment depth 803 to 1342 cm in all levels.

Coscinodiscus lanceolatus Castr.

CASTRACANE 1886 p. 164, Pl. 17, fig. 19.

Icon nostr. Pl. II, fig. 23, 24, 25.

Synonyms: *C. rhombicus* Castr. (CASTRACANE 1886, p. 164, Pl. 22, fig. 11) *C. naviculoides* Tr. & Witt (TRUAN & WITT 1888, p. 44, Pl. 2, fig. 10) *C. punctatus* var. *rhombicus* (Castr.) RATTRAY 1890, p. 99).

Little attention has hitherto been paid to the group of *lanceolate* to *rhombic* forms which so far (whether rightly or wrongly is left an open question) has been assigned to the giant genus *Coscinodiscus*. As a consequence the forms have often been illustrated and named though not critically examined. The following attempt at investigation is to be considered as a provisional experiment stimulated by the relatively frequent appearance of the representatives of the group in the bottom samples examined. For a thorough study I do not dispose of sufficient material for comparison.

As far as I can see from literature, 14 forms which may be referred to the group *lanceolate-rhombic Coscinodisci* (?) have been described up to now:

Coscinodiscus punctatus Ehr. 1840.

Coscinodiscus rhombicus Grun. 1880.

Stoschia palacea Grun. 1880. = *Coscinodiscus paleaceus* (Gr.) Rattr.

Rutilaria recens Cl. 1881.

Coscinodiscus rhombicus Cast. 1886 = *C. punctatus* var. *rhombicus* Rattr.

Coscinodiscus naviculoides Tr. & Witt 1888.

Coscinodiscus lanceolatus Cast. 1886.

Cymatosira ? *biharensis* Pant. 1889.

Coscinodiscus punctatus var. *rhombicus* Rattr. 1890.

Coscinodiscus lewisianus var. *morenensis* Rattr. 1890.

Coscinodiscus lewisianus var. similis Rattr. 1890.

Coscinodiscus gracilentus Rattr. 1890.

Cymatosira anderssonii Hanna 1932.

Cestodiscus lewisianus Mann 1937.

The more or less elliptical to lanceolate outline of this group is not constant but varying within quite narrow limits. All forms are characterized by rather solid valves and a comparatively coarse areolation, its density also varying within relatively narrow margins, mostly about 3—4 1/2 areolae in 10 μ; we know that the density of areolation has no great taxonomic significance within this group. Nor does a more or less developed central area seem to be constant or typical. The difference between circular and polygonal areolae, which previous authors considered important, is in this case, as in many others, of no great value. The shape of the areolae usually depends (at all events within this group) on the valve being intact, viz. their chambers being also intact and having pore membranes and sieve membranes:[1]) — in this case the areolae (= chambers) appear polygonal — or, if the sieve membrane with the lateral chamber walls is broken off (»arrachement» as per PERAGALLO), the areolae appear detached and round. Compare our figures 24 and 25 on Pl. II illustrating the same valve under different focussing. Only a small part of the sieve membrane and the lateral chamber walls are intact and on focussing on the latter the polygonal areolae appear ± distinctly, as shown on the photomicrograph Pl. II, fig. 24. On the major part of the valve the sieve membrane and the lateral chamber walls are missing and the areolae appear circular (Pl. II, fig. 25) when focussing on the pore membrane.

More important from a taxonomic point of view is the presence or absence of marginal spines referred to in the description of *Coscinodiscus rhombicus* Grun., *Rutilaria recens* Cl. and *Cymatosira biharensis* Pant. It seems to me that the importance of this character is somewhat overrated. *Cymatosira biharensis* is unmistakably marked with long spines (although I doubt that the general character of this form justifies its being included in the genus *Cymatosira*); the spines of *C. rhombicus* Grun. are not always visible according to GRUNOW's description; except for the presence of marginal spines, *Rutilaria recens* Cl. is practically identical with *C. paleaceus* having in common even the interstitial areolae. A study of original material is urgently called for; until then I look upon the three species as synonyms, giving priority to the name *C. rhombicus* Grun. The outline of the spineless forms (the greater part of this group) may be narrow or broadly lanceolate to rhomboid, its areolation coarser or finer and either irregular or showing the characteristic type of areolation of *C. lewisianus:* apical straight or slightly rounded rows parallel to the apical axis; transapical rows curved and diverging from the transapical axis; central space forming irregular circular figures. On the basis of the latter structure RATTRAY (1890, p. 150) describes two varieties of *C. lewisianus:* var. *moronensis* which was not illustrated nor adequately diagnosed and var. *similis* (1890, p. 150, Pl. 3, fig. 10), the outline of which corresponds with the group here discussed, its structure being very closely akin to the typical form of *C. lewisianus.*

EHRENBERG's species *Coscinodiscus punctatus* seems to be very doubtful and according to GROVE's (see RATTRAY l. c., p. 99) statement, due to a confusion with *Actinocyclus.* In the original material (CLEVE & MÖLLER No. 57, Richmond, Virginia) I found *Actinocyclus ellipticus* only. The form *C. punctatus* must be considered as very dubious until it has been definitely elucidated.

HANNA (1932, p. 187, Pl. 10, fig. 6) describes a new form: *Cymatosira andersoni* Hanna,

[1]) Nomenclature according to KOLBE 1951.

characterized by the presence of marginal spines (the statement is somewhat unclear on this point), regular parallel rows of areolae along the apical axis, a central area and — judgeing from the figure — a regular marginal structure. Within the group discussed, to which the form in any case belongs, the latter two characters are of no taxonomic value; I have observed central areas even in other species of this group. Judgeing by the general impression I definitely consider HANNA's form to be a *C. paleaceus* (Gr.) Rattr. although its areolation is somewhat closer.

With respect to the above remarks the group of rhombic-lanceolate *Coscinodiscus*-species could be grouped in the following manner, which however for the time being should be taken as a provisional taxonomic aid only.

1. Valves with marginal spines — *Coscinodiscus rhombicus* Grun. (Synonyms: *Cymatosira biharensis* Pant. and *Rutilaria recens* Cl. (?)

1*. Valves with no marginal spines

2. Outline narrow-lanceolate, often with asymmetric ends; the presence of interstitial meshes quite frequent. *C. paleaceus* (Grun.) nov. comb. (Synonym: (*Cymatosira andersoni* Hanna.)

2*. Outline broad-rhombic to rhombic-lanceolate.

3. Areolae 6—8 in 10 μ — *C. punctatus* Ehr. (?)

3*. Areolae less than 6—8 in 10 μ.

4. Areolae irregularly spread — *C. lanceolatus* Castr. (Synonyms: *C. naviculoides* Tr. & Witt, *C. punctatus* var. *rhombicus* Rattr.)

4*. Areolae in slightly curved longitudinal chains $\pm$ parallel to the apical axis (*C. lewisianus* — structure) — *C. lewisianus* var. *similis* Rattr. (Synonyms: *C. lewisianus* var. *moronensis* Rattr.

By including a variety of *C. lewisianus*, the key may not seem to be logical. With regard to this it should be said that the position of this form within the genus *Coscinodiscus* is on the whole disputable.

Altogether I do not think that the entire group of elongate *Coscinodisci* can be held in the long run and should probably be separated from the genus *Coscinodiscus*. This, however, should be done after a complete and thorough investigation of the group.

A study of the discussed very vague group of *Coscinodiscus lanceolatus* would on the other hand be an important task. It should be mentioned that in rare cases forms having $\pm$ distinct ocelli were met with in the material, thus passing over to the genus *Actinocyclus*. In material 76/1261 for instance, I observed a purely elliptic form with very coarse polygonal areolation and a distinct ocellus at an ellipse-pole.

Coscinodiscus lanceolatus was observed comparatively often in some of the cores; the longest specimen had a length of 120 μ, a breadth of 45 μ and a density of areolae in its central part of about 3 areolae in 10 μ. All forms of this group are apparently extinct.

Localities: Cores 58/60, 58/485, 58/623, 58/893, 59/401, 59/747, 76/23 and 76/41.

Coscinodiscus lewisianus Grev. (nec *Cestodiscus lewisianus* Mann).

A. S. Atl. Pl. 66, fig. 120.

RATTRAY 1890, p. 150.

Icon nostr. Pl. II, fig. 21.

This species is easily recognised by its shape and characteristic areolation. It is known as far as I am informed — only from the Polycystine limestone of the Nicobar Islands, from some North American Tertiary deposits and from the Tertiary of Hungary. The

presence of the typical form in a number of bottom samples of the Equatorial Pacific is therefore not without interest.

MANN (1937, p. 30, Pl. 3, fig. 6) proposed to transfer *Coscinodiscus lewisianus* to the genus *Cestodiscus*. However welcome any reduction of the enormous genus *Coscinodiscus* might be, I cannot recommend it in this case. If MANN considers *C. lewisianus* being in better accordance with the conception of *Cestodiscus* (without explaining his view any further) he is decidedly in the wrong. The latter genus does not show the characteristic elongate outline of the *Coscinodisci lanceolati* nor does *C. lewisianus* possess the typical radial processes[1]) of the *Cestodisci*. But above all, the form which he illustrates as *C. lewisianus* (cf. l. c. Pl. 3, fig. 6) lacks the characteristic areolation, so typical for the genuine *C. lewisianus*. MANN's figure represents very probably *C. lanceolatus* Castr. (see above); MANN refers to the latter but without correctly conceiving the difference between that form and *C. lewisianus*. (cf. further the discussion at *C. lanceolatus*).

Localities: Core 59/890, Core 76 — spread in many levels.

Coscinodiscus lewisianus var. *similis* Rattr.
RATTRAY 1890, p. 150, Pl. 3, fig. 10.
Icon nostr. Pl. II, fig. 22.

In outline this variety closely resembles *C. lanceolatus* but differs from this latter form by the areolation which in character is identical with *C. lewisianus*.

RATTRAY (l. c.) described a further variety: *C. moronensis*. The chief difference between these two forms seems to be that the areolae of var. *similis* are circular whereas the areolae of var. *moronensis* are polygonal, forming a closed network of areolae. This character should not, in this case, be considered as being a taxonomical criterion, as has been discussed before (p. 30). Previous authors have already pointed out — most recently and very emphatically HUSTEDT (1927) — that the same forms at times may occur with a closed net-work of polygonal areolae touching each other, as well as with a system of round areolae (»offenes» and »geschlossenes Areolennetz»). The areolae of forms with coarse markings are typical chambers (usually half-closed chambers, cf KOLBE 1948, p. 6). A focussing on the pore membrane or on the inside of the chamber is sufficient to make the areolae appear either round or polygonal. As a variety should not be based on a dubious character, I propose to unite the two forms: var. *similis* and var. *moronensis*. Var. *moronensis* is not illustrated and when studying the original material from Moron, I could only find the typical var. *similis*. It may therefore be that var. *moronensis i s* var. *similis* in reality. The valid name should in any case be: *Coscinodiscus lewisianus* var. *similis*.

Localities: Cores 58/317, 58/485, 58/890.

Coscinodiscus lineatus Ehr.
VAN HEURCK 1880, Pl. 131, fig. 5.
HUSTEDT 1927, I, p. 392.

This cosmopolitan marine form belongs also in our material to the most widespread and frequent species. It is present in many levels and in about 60 per cent of all cores. Generally provided with single (1 to more) stronger single processes in addition to the numerous marginal spines as HUSTEDT (l. c.) has pointed out.

Localities: in most cores.

Coscinodiscus lineatus var. *ellipticus* var. nov.
Icon nostr. Pl. 11, fig. 15.

In some cores a variety with an elliptical outline appeared in addition to the typical form and was further characterized by the constant presence of a strongly developed solitary spine. This spine was always situated in the middle of the long side of the valve and at some distance from the border. The uneven, group-like occurrence of the form was quite remarkable.

[1]) »intra-marginal shortly tubular processes .... connected with the centre by means of a distinct furrow . . .» (CASTRACANE 1886, p. 122).

Diagnosis: elliptical valves 50 to 96 μ long, 44 to 80 μ broad, areolae 5 to 6 in 10 μ, marginal striae 9 to 11 in 10 μ, otherwise: character of the typical form.

Localities: Cores 47/249, 47/300 (not rare), 74/1022, 75.

After having studied the present material I think with HUSTEDT (l. c.) that one should not attribute too much importance to the marginal and solitary spines as specific characters within this group. It is the same (in some cases) with the number of central markings (nodules). (cf the discussion at *C. nodulifer*).

Coscinodiscus marginatus Ehr.

HUSTEDT, 1927, I, p. 416.

Coscinodiscus marginatus occurs in many cores of the present material but not very frequently. One would a priori assume a greater abundance of this kind of thick walled forms in the bottom samples. Its comparative scarcity in the material would indicate a minor resistance against corrosion — in spite of its wall strength — or perhaps its scarcity in the plankton. Most frequent in Core 76; as the core its particularly rich in Pre-Quaternary species it is possible that the form was more abundant in the Equatorial Pacific during the Pliocene than it is at present.

Localities: single specimens in many cores, relatively frequent in Core 76.

Coscinodiscus nitidus Greg.

PERAGALLO 1897, Pl. 117, fig. 11, 12.

HUSTEDT 1927, I, p. 414.

Coscinodiscus nitidus is extremeley rare in the present material; all in all I have only observed about 5—6 specimens.

Localities: Cores 38/60, 38/340, 58/530.

Coscinodiscus nodulifer A. Schm.

A. S. Atl. Pl. 59, fig. 20—23.

KARSTEN 1907, III, p. 364, Pl. 36 fig. 6.

HUSTEDT 1927, I, p. 426.

Icon nostr. Pl. III, fig. 35, 36, 37.

Chapter 4 has been dedicated to this characteristic form of the Equatorial Pacific; only a few details may be added.

The great range of size variation from 13 μ to more than 200 μ diameter has already been mentioned, as well as the fact that an average size of about 40 μ was by far the most frequent. The areolation fluctuates within the limits of 3 to 6 in 10 μ measured on half the radius.

The »nodule» is a papilla-like membrane thickening (central papilla), which is probably perforated by a narrow canal representing a mucous pore, as is well known from many forms examined by the electron microscope. *Coscinodiscus nodulifer* may show one or (rarely) several central papillae; very seldom the nodule may be lacking; in these cases it is difficult to distinguish the form from *C. radiatus*. The central papilla is in general a vague character: sometimes normal valves of *C. lineatus* and *excentricus*, also showing »nodules» were observed in the present material. The papilla may in extreme cases grow out into a short, sometimes bent spine or appendix.

Contrary to the leading taxonomists LOHMAN (1941, p. 72) lays stress upon the systematical significance of the number of central papillae. I cannot agree with him in this. Individuals with single and (rarely) several nodules may be found in the same level of a core. Therefore LOHMAN's assumption that *Coscinodiscus nodulifer* and its »var. *apiculata*» belong to different ecotypes hardly holds true. The observation mentioned above, demonstrating that nodules can appear also in species normally not carrying papillae shows that the presence or number of central papillae are not always a specific character at least not with regard to certain centric forms.

It should further be mentioned that detached rings are frequently seen, undoubtedly belonging to *C. nodulifer*, as these structures at times are still connected with the valves of this species. The rings (cf. Pl. III, fig. 37) lie probably between the disc and the girdle and close the marginal chambers in pervalvar direction.

While small and medium-sized specimens of

C. nodulifer have only an irregularly radial disposition of areolae, the large individuals show distinct secondary spirals as seen in Pl. III, fig. 35.

Localities: in all diatomiferous cores and in nearly all levels with the exception of Core 76, in which the form is present only in the upper layers and disappears at a depth of about 5 m.

Coscinodiscus obscurus A. Schm.

A. S. Atl. Pl. 61, fig. 16.

Hustedt 1927, I, p. 418.

This species, strangely enough, is limited to Core 76; in this core it appears in the levels between 181 and 1342 cm sediment depth being relatively frequent in the zone 76/1121 —76/1342.

Coscinodiscus oculus iridis Ehr.

A. S. Atl. Pl. 63, fig. 6.

Rattray 1890, p. 111.

Hustedt 1927, I, 454.

Coscinodiscus oculus iridis is extremely rare in the examined bottom samples.

Localities: only a few specimens in Cores 38/100 and 47/300.

Coscinodiscus paleaceus (Grun.) Rattr.

Rattray 1890, p. 149.

Illustrations: van Heurck 1880, Pl. 128, fig. 6 (as Stoschia).

Icon nostr. Pl. III, fig. 32 a, 32 b.

Synonyms: ? *Rutilaria recens* Cl. Cleve 1881, p. 19, Pl. 4, fig. 57. ? *Cymatosira andersonii* Hanna. Hanna 1932, p. 187, Pl. 10, fig. 6.

Regarding the taxonomy of this form cf. the discussion of *C. lanceolatus* (p. 29).

Coscinodiscus paleaceus shows in our material a tendency to develop asymmetric ends (see the figure in van Heurck's Synopsis l. c.). The network of areolae is always closed and one frequently observes distinct interstitial meshes.

The length of the form varied in the examined material within considerable limits: length 43—99 μ, width rather constant 11 to 13 μ, areolae 5 to 6 in 10 μ.

Except for some rare finds in Core 60, *C. paleaceus* is confined to Core 76. In this core the form is present in all levels sometimes rather frequently, especially in the deeper sediment layers.

Conscinodiscus perforatus var. *cellulosus* Grun.

A. S. Atl. Pl. 114, fig. 5.

Grunow 1884, p. 23.

Hustedt 1927, I, p. 446.

Localities: very rarely found in Cores 40/190 and 60/288.

Coscinodiscus plicatus Grun.

Grunow 1884, p. 34 and 21, Pl. 3, fig. 10.

A. S. Atl., Pl. 59, fig. 1.

Rattray 1890, p. 82.

The group of plicated *Coscinodisci* which Grunow (l. c.) included in a sub-genus with the somewhat misleading name *Pseudostephanodiscus*, seems to be a morphologically self-contained group. The series *C. lacustris* — var. *septentrionalis* — var. *hyperboreus* — *plicatulus* (?) — *plicatus* is morphologically (not ecologically) united through gradual transitions. The common features are: plication, $\pm$ radial areolation, circlet of spines, the taxa of the series differing chiefly by the shape of the areolae and their greater or lesser density. In my opinion too little consideration has been given to the type of plication. In A. Schmidt's (l. c.) figure of *C. plicatus* the plication intersects the valve in a straight line. As it is difficult to reproduce the three-dimensional aspect of the form, it is not clearly illustrated by Grunow (l. c.). In the present material the plication runs in a clear sigmoid line and the surface of the valve has a gibbosity and a depression which, however, do not quite reach the margin. Sometimes no pronounced plication is seen, but only the two opposing gibbosities, as illustrated by Hustedt (1927, I, p. 433) in the case of *C. lacustris*. In the explanation of his figure Schmidt (l. c.) mentions: *C. plicatus* Gr.: »on one side convex, on the other concave, therefore to be placed near *C. excavatus*». This is

somewhat exaggeratedly expressed, but agrees, however, to a certain extent with the character of the plication. It would be interesting to ascertain, on suitable material, whether the type of plication is sufficiently constant and may be used as a specific character within the group of plicated *Coscinodisci.*"

The specimens in the present material are identical with those of GRUNOW's original material (Nicobar Islands) and differ only by their wider spacing of the marginal spines (about 3 in 10 μ).

Judgeing from literature, *C. plicatus* seems to be extinct and known from Tertiary sediments only.

Localities: in the present material *C. plicatus* was found only in Core 76, and exclusively in its deepest levels from 741 cm to the end of the core (1 342 cm).

Coscinodiscus radiatus Ehr.

A. S. Atl. Pl. 60, fig. 1—6, 9—10.

PERAGALLO 1897, Pl. 117, fig. 3.

HUSTEDT 1927, I, p. 420.

Widely spread in the present bottom samples.

Localities: Cores 38/6, 38/60, 59/610, 76/23, 76/281, 76/1021, 76/1161, 76/1181, 76/1342.

Coscinodiscus tabularis Grun.

A. S. Atl. Pl. 57, fig. 43.

RATTRAY 1890, p. 135.

HUSTEDT 1927, I, p. 427.

Icon nostr. Pl. I, fig. 12.

A few specimens of this form were observed in some cores of the present material. These agreed entirely with the figures by A. SCHMIDT and HUSTEDT cited above. All of them gave the impression of being not normal but corroded valves. This impression was emphasized by the frequently notched border (cf. fig. 12) which resembled a circular saw and was probably caused by the disappearance of the marginal apiculi.

Localities: sporadic in Cores 38/6, 39/350, 39/461, 45/301, 60/595, 60/1001.

Coscinodiscus tabularis var. *egregius* Grun.

A. S. Atl. Pl. 57, fig. 39.

RATTRAY 1890, p. 70.

HUSTEDT 1927, I, p. 428.

This form, easily distinguished by its peculiar marginal structure (cf. HUSTEDT l. c.) was met with in our material but in a small number of specimens.

Localities: in some levels of the Cores 38, 39, 40, 76.

Coscinodiscus tuberculatus Grev.

GREVILLE 1861, p. 42, Pl. 4, fig. 6.

GRUNOW 1888, p. 30, Pl. 3, fig. 29 (var. *monicae*).

A. S. Atl. Pl. 57, fig. 41.

RATTRAY 1890, p. 34.

Icon nostr. Pl. I, fig. 11.

The resemblance of this form with *C. curvatulus* var. *minor* was mentioned in the discussion of the latter variety. There seems to be a certain disagrement between the authors in respect of the present form:

GREVILLE (l. c.) mentions in his diagnosis of the typical form a kind of central area, »a deep pore-like umbilicus», which later authors ignore;

A. SCHMIDT (l. c.) emphasizes in his drawing and explanation of figure the remarkable border processes but he figures no central area;

GRUNOW (l. c.) writes about his var. *monicae* that the marginal processes were smaller than in *C. tuberculatus* to which the form is otherwise related;

RATTRAY (l. c.) says of the same variety: »the apiculi interfasciculate, more evident » (than in the typical form).

A further remark by RATTRAY about the typical form is suggestive (l. c.): »This species cannot be united with *Aulacodiscus* as proposed with some doubt in the second edition of HABIRSHAW's Catalogue .....». From this observation it may be assumed that the processes seemed to be so conspicuous as to warrant a suggestion to include the form into the genus *Aulacodiscus*.

From the above comparison it is clear that *C. tuberculatus* is characterized by obvious processess. In our material the form was abundant only in the deep levels of Core 76; the figured specimen (Pl. 1, fig. 11) had — as most of the measured specimens — the following dimensions: diameter 38 μ, areolae — 4 1/2 in 10 μ, marginal striae — 10 in 10 μ.

According to RATTRAY, and contrary to GRUNOW, our form might be characterized as var. *monicae*. The type, as well as the variety are apparently known from Pre-Quaternary layers only.

Locality: Core 76, rather frequent from level 761 cm to the lower end of the core.

Coscinodiscus vigilans A. Schm.

A. S. Atl. Pl. 114, fig. 12.

RATTRAY 1890, p. 19.

Icon nostr. Pl. I, fig. 13 and 14.

Synonym (?): *C. subconcavus* A. Schm. in A. S. Atl. Pl. 59, fig. 13.

A very peculiar form, which at first sight does not resemble a diatom. The diameter of the rather frequent individuals varied between 28 and 51 μ, the areolation between 1.8 and 4 areolae in 10 μ; the border structure was in most cases not well defined but could in some specimens be measured as 10 areolae in 10 μ.

C. subconcavus A. Schm. seems to be only a smaller form within the size variation of *C. vigilans*. I cannot see any difference in the figures from SCHMIDT and the diagnoses from RATTRAY; the localities of both species (Simbirsk for *C. subconcavus*, Archangelsk-Kurojedowo for *C. vigilans*) may also support my opinion.

The structural character of *C. vigilans* may be somewhat reminiscent of *Stephanopyxis*, but the very flat valves (as shown by the photomicrographs) and the complete lack of spines, exclude a comparison. The specimens observed are identical with those in SCHMIDT's original material (Archangelsk-Kurojedowo).

MANN (1907, p. 268, Pl. 50, fig. 5) describes *Stictodiscus gelidus*, a form which is extraordinarily similar to *C. vigilans*. With regard to the general character of its markings, the size of the areolae and even the vermiform central pore, *Stictodiscus gelidus* might be identical. with *C. vigilans*. On the other hand MANNS form is much larger (diameter 58—105 μ as compared with 28—51 μ of our specimens) and shows 12—18 radiating but irregular lines common in the genus *Stictodiscus*. On account of this character I do not suggest uniting the two forms but recommend a further investigation of them.

C. vigilans has apparently been little observed and is known only from Tertiary localities.

Localities: only in Cores 58 and 76; in the former it was found in many levels, in the latter only at a sediment depth of 381 cm.

Craspedodicus Ehr.

Craspedodiscus coscinodiscus Ehr.

A. S. Atl. Pl. 66, fig. 3, 4.

DE TONI 1891, p. 1190.

Icon nostr. Pl. I, fig. 4.

The specimens of our material agree with var. *nancoorensis* Grun. (A. S. Atl. Pl. 66, fig. 5); on account of the large material available for comparison, I do not consider a separation of the variety justified. The small deviations in the areolation and the more or less pronouned projection of the exterior ring are not constant and too insignificant.

As fas as I can gather from literature, *Crasp. coscinodiscus* is a form met with in the Miocene and Pliocene (very frequently so in the Polycystine limestone from the Nicobar Islands) but now probably extinct. Contrary to this, however, is the peculiar statement by O'MEARA (1876) who found it near the Irish Coast; this would be the only recent finding which, perhaps, should be looked upon with some scepticism.

Localities: very rare in Cores 59/180 and 60/240; rarely in the upper levels of Core 76, but regularly and rather frequently occurring in all deeper layers from about 8 m to the lower end of this core.

Cyclotella Kütz.

Cyclotella stylorum Brightw.

Hustedt 1927, 1, p. 348.

Localities: a few specimens in Cores 38, 40, 41, more frequent in Cores 59, 62, 93.

Denticula Kütz.

Denticula nicobarica Grun.

Grunow 1867, p. 67, Pl. I a, fig. 5.

Van Heurck 1880, Pl. 49, fig. 3.

De Toni 1891, p. 560.

Very likely an extinct form, hitherto known only from the Polycystine limestone from Nankauri, Nicobar Islands.

Localities: exclusively in Core 76 from a sediment depth. of 541 cm to the lower end of the core.

Diploneis Ehr.

The two representatives observed in the material of this chiefly benthonic genus, were found exclusively in the proximity of the Galapagos Islands; a few specimens only.

Diploneis crabro Ehr.

Hustedt 1927, II, p. 616.

Localities: Cores 38/60, 39/322, 39/461.

Diploneis suborbicularis (Greg.) Cl.

Hustedt 1927, II, p. 612.

Localities: Cores 39/461 and 40/190.

Ethmodiscus Castr.

Ethmodiscus rex (Rattr.) Hend.

Hendey in Wiseman & Hendey 1953, p. 51, Pl, I, fig. 1—6, Pl. II, fig. 1—3.

Synomyms: *Coscinodiscus rex* Wallich 1869, p. 688.

Coscinodiscus Gazellae Janisch 1879.

Ethmodiscus gigas Castracane 1886, p. 169.

Antelminella gigas Schuett (?).

Ethmodiscus gazellae Hustedt 1927, II, p. 375.

The giant plankton form *Ethmodiscus rex* characterized by an extremely long pervalvar axis and vermiform apiculi (mucuos pores) spread all over the valves, belongs according to Hendey decidedly to the genus *Ethmodiscus*.

Hendey (1. c.) gave a full description and excellent figures of the form with a critical discussion of its taxonomy.

Fragments of valves were comparatively rarely observed, whereas fragments of mantles were very frequent. It would appear as if the valves of *Ethmodiscus rex* are quite resistant to corrosion: most fragments were broken but did not show any signs of dissolution.

Mantle fragments of *Ethmodiscus rex* and — more seldom — of other large plankton forms were grouped collectively under the name of »Fragments» (cf. discussion under this heading). Together with *C. nodulifer* and *Nitzschia marina* they formed quantitavely one of the most important constituents of the diatom sediment in our material.

Localities: Strictly speaking only such localities should be registrered, where fragments of the central part of the disc with its characteristic curved tube-like structures were observed. Such fragments were found in the cores 38, 39, 40, 76 and 105; on the other hand mantle fragments belonging very probably to *Ethmodiscus rex* were very frequently found in practically all of the Pacific cores.

Ethmodiscus rex seems to have a very wide geographic range: besides the localities in the Pacific I have observed it in many cores of the Equatorial Atlantic.

»Fragments»

Castracane 1886, Pl. 14, fig. 1, a, b, c.

Hustedt 1927, I, p. 375.

Icon nostr.: Pl. IV, fig. 1.

Under this heading I understand large and flat fragments with a ± delicate structure (parallel rows of dots) regularly occuring in nearly all cores and levels. Castracane (1. c.) has already illustrated them; this author believes them to be fragments of *Ethmodiscus* (1. c. 170).

I also think that in our material in most cases, but not exclusively, those objects were *Ethmodiscus*-fragments. They were surely frag-

ments of valve mantles of plankton forms; our knowledge of the mantles and connective zones of marine diatoms being still rather rudimentary, it is difficult to identify such fragments. In many cores the fragments could be definitely identified as belonging to *Ethmodiscus* (*Coscinodiscus*) *rex*, as mantle fragments with parts of the valves attached were found. The bulk of the fragments, apparently an essential part of the marine sediments, thus seems to consist of mantle-fragments of *Ethmodiscus* and presumably other large plankton forms.

In nearly all cores and levels of the Equatorial Pacific.

Gephyria Arnott

Gephyria media var. *ornata* (Grun.) Fricke
A. S. Atl. Pl. 232, fig. 7—13.

Synonyms: *Entopyla ornata* Grunow 1867, p. 97, Pl. I A, fig. 17.

(?) *Entopyla Rimboeckii* Pantocsek 1889, 11, Pl. 20, fig. 312.

Only two valves, fully agreeing with specimens from the Polycystine limestone from Nankauri (Nicobar Islands).

Locality: 76/23.

Glyphodesmis Grev.

Glyphodesmis williamsonii (W. Sm.) Grun.
Hustedt 1927, II, p. 124.

Locality: Core 76/121 — only two valves.

Glyphodesmis williamsonii f. *inflata* nov. f.

Differs from the typical form by a slight inflation in the middle part of the valve; in size and structure entirely identical with the species.

Locality: Core 38/120 (in the region of the Galapagos Islands).

Grammatophora Ehr.

Grammatophora hamulifera Kütz.
Hustedt 1927, II, p. 40.
Locality: Core 39/186.

Grammatophora undulata Ehr.
Hustedt 1927, II, p. 48.
Locality: Core 76/41.

Hemidiscus Wallich.

Hemidiscus cuneiformis Wall.
Hustedt 1927, I, p. 904.
Hustedt 1940, in A. S. Atl. Pl. 435, fig. 1 ff.

Hemidiscus cuneiformis was the only representative of the genus in the total material examined. The form belongs to the most frequent species in the cores investigated and is relatively abundant in almost every one of the diatomiferous sediments of the area.

In the Equatorial Pacific the species showed a very great variability — a peculiarity pointed out by Hustedt (l. c.). In our material not only all varieties illustrated by Hustedt were often seen in the same field of vision, but one may say that no individual looked like the other and each specimen presented one of the many transitions between extreme forms. The size of the individuals also varies within surprisingly wide limits: while the smallest specimens were about 20 μ long, the giant forms in Core 61 (see below) attained a length of more than 300 μ.

In 1927 (l. c.) Hustedt describes some of the extreme variations of *Hemidiscus cuneiformis* as varieties, but ascribes them later (1940 l. c.) the taxonomic rank of formae only. After having studied the extensive material of the Swedish Deep-Sea Expedition, I fully agree with his point of view.

In a comprehensive material containing several strains or populations of an organism varieties (being genotypic units) would be detected by higher frequencies of certain variants of the organism. This was not the case either in the present or probably in Hustedt's material: no numerical preference of certain form variations could be observed.

Interesting indeed was the occurrence of colonies of *Hemidiscus cuneiformis*. The individuals clung together with the ventral sides; as a *Hemidiscus*-cell has a cuneiform section along the transapical axis, the colonies bear a certain resemblance to a peeled lemon (cf. Icon nostr. Pl. IV, fig. 48).

In one part of Core 61 (746 cm to 766 cm sediment depth) a very definite maximum of large individuals was observed; specimens with an average length of more than 250 μ and up to 312 μ dominated (see General Section, p. 13).

Localities: in most cores and their levels, frequent to very frequent.

»Liostephania» Ehr.

Icon nostr. Pl. 1, fig. 5, 6, 7.

The peculiar structures included in this name are not rare in some of the cores. In spite of PAYNE's (1922) studies, nothing definite can be said about their real nature. According to PAYNE they are casts of diatom valves[1]) — *Asterolampra* and *Asteromphalus* — which have arisen by way of filling up the valve with silica. Strangely enough these casts are restricted to the mentioned genera o n l y.

Such formations might perhaps be brought into connection with the so-called resting stages of diatoms. Among recent forms there are some genera regularly producing resting stages, chiefly *Chaetoceros*, *Attheya*, *Rhizosolenia* and sometimes *Melosira*. In the *Pennales*, however, resting stages have been observed much more rarely; one such case has been described by KOLBE and KRIEGER (1942) for *Amphora*. The *Chaetoceros* resting stages are characteristic and well defined structures, totally unlike the vegetative cells; in other genera these formations are often such that one would hardly at first sight connect them with diatoms (cf. KOLBE & KRIEGER l. c.). This subject is still rather unexplored.

The illustrations Pl. I, fig. 5 to 7 show some *Liostephaniae* which were observed in the present material. It is remarkable that hardly any one of them can be brought into relationship with forms represented in our material.

[1]) According to PAYNE (l. c. p. 7) the *Liostephaniae* »... are formed inside the diatom valves ...».

»They are merely impressions or casts of the sculpture of the diatom valve, taken in silex, and generally very poorly».

All *Liostephaniae* seem to belong to forms from earlier geological periods. This may explain their greatest abundance in Core 76, which contains most of the Pre-Quaternary species.

Localities: Cores 38/140, 58/642 and 76 (many levels).

Liriogramma nov. gen.

Valve flat, elongated, more or less lanceolate to ovoid. Girdle view, so far unknown. Valve-structure: somewhat irregular apical rows of punctae decussated by sloping transapical rows. The central part of the valve is occupied by a large conspicuous hyaline and strongly lustrous marking, not unlike a conventionalized heraldic lily »Fleur de lis». It consists of six separate parts contacting each other: two prolonged formations of different length, running in an apical direction in a pseudo-raphe (always?) and four shorter and broader parts disposed symmetrically around the centre of the valve. The marking represents probably an attenuation of the cell membrane, as shown by its optical reaction.

The central marking as well as the somewhat unusual and irregular areolation, gives the impression of a certain primitiveness; the form is reminiscent of certain geologically old species with still undeveloped areolation. Judgeing by its general character, *Liriogramma* might be placed in the system with *Actinodisceae* — *Asterolamprinae*.

The primitiveness of the species described below may give the impression of its being a *Liostephania*-form, thus an imperfect cast of a diatom valve. This is, however, out of the question in this case, as the marking and areolation of the present species are altogether too distinct and clean-cut to be mistaken for *Liostephania*-forms with their vague traces of a sculpture.

No raphe could be detected in the two longitudinal lines of the central marking, perhaps owing to the strong lustre of the

marking. Now and then at a certain illumination I thought I perceived a thin raphe fissure; this observation however was very uncertain. In any case, no central nodules or pores could be noticed.

So far, only one species has been observed:

Liriogramma petterssonii nov. sp.

Icon nostr. Fig. 9 and Pl. IV, fig. 46 a, 46 b.

Nomen nudum?: *Asteromphalus sarcophagus* Wall.

Wallich 1860, p. 47, Pl. 2, fig. 12.

Characters of the genus. Length 56 μ, breadth 16 μ, transapical striae 10 in 10 μ.

Dedicated to Professor Hans Pettersson the leader of the Swedish Deep-Sea Expedition.

Locality: Core 38/160.

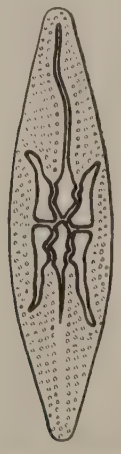


Fig. 9. *Liriogramma petterssonii* nov. sp.

It is possible that Wallich (1860) had this form before him when he described *Asteromphalus sarcophagus*. But the optical instruments of his time did not really allow a precise study of the small forms and the drawing as well as the description by Wallich are insufficient. *A. sarcophagus* is illustrated with an *Asteromphalus*-structure (probably conventionalized), whereas the valve structure of *Liriogramma petterssonii* has a specific primitive character, which has nothing in common with the complicated structure of *Asteromphalus* and which requires the creation of a new genus.

Melosira Ag.

Melosira sulcata var. *biseriata* Grun.

Peragallo 1897, Pl. 119, fig. 14.

Hustedt 1927, I, p. 278.

Localities: some specimens in Cores 38/160, 39/2, 39/291.

Navicula Bory

Navicula approximata Grev.

A. S. Atl. Pl. 3, fig. 17.

Cleve 1894, II, p. 62.

Icon nostr. Pl. II, fig. 16.

Mr. N. Ingram Hendey, who is about to publish a critical study on the complicated group *Naviculae lyratae* was kind enough to check the determination of the form.

Locality: Core 39/186.

Navicula lyra var. *ehrenbergii* Cl.

A. S. Atl. Pl. 2, fig. 16.

Cleve 1894, II, p. 63.

Locality: Core 40/150.

Navicula spectabilis var. *angelorum* Cl.

Cleve 1881, p. 8, Pl. 2, fig. 20.

Locality: Core 39/291.

The three Navicula-species are typical benthonic forms; characteristically enough, they were found only in the proximity of the Galapagos Islands.

Nitzschia Hass.

The genus *Nitzschia* is represented in the present material only by one species: *Nitzschia marina* Gr. This species belongs to the most widespread and abundant forms in the bottom samples of the Equatorial Pacific. The absence of the other plankton forms of *Nitzschia* and *Pseudo-Nitzschia* in the sediments may be due to the delicacy and weak silification of their cell walls, which soon dissolve after the death of the individual.

Nitzschia marina Grun.

Grunow in Cleve & Grunow 1880, p. 70.

van Heurck 1880, Pl. 57, fig. 26, 27.

Peragallo 1897, p. 272, Pl. 72, fig. 23, 24.

Icon nostr. Pl. III, fig. 38, 39, 40.

Synonyms: *Synedra Gaussi* Heid. in HEIDEN & KOLBE 1927, p. 561, Pl. 5, fig. 112—113;

Synedra atlantica CASTRACANE 1886, p. 53, Pl. 25, fig. 16;

Fragilaria sublinearis H. V. HEURCK, 1909, p. 25, Pl. 3, fig. 39, 41.

Fragilaria pliocena J. BRUN 1891, p. 28, Pl. 14, fig. 7.

(?) *Pseudonitzschia fossilis* FRENGUELLI 1949, p. 118, Pl. 1, fig. 6, 7.

After *Coscinodiscus nodulifer* this form belongs to the leading species in the present samples.

At first the author had some doubts as to which genus it should belong. Beyond question, the form is identical with *Synedra Gaussi* Heid. which a comparison with the original material of the »Gauss» Expedition definitely proves. *Synedra Gaussi* differs considerably in its structure from all known *Synedra* species, approaching *Fragilariopsis antarctica* (Castr.) Hust. and therefore one of the authors, at that time (HEIDEN & KOLBE, l. c., p. 561), assumed that *Synedra Gaussi* represents a connecting link between the two genera. However, the two genera differ essentially in one respect: whereas *Fragilariopsis antarctica* (which was abundant in some samples of the »Gauss» material) has plain margins, those of the HEIDEN-form show 2 distinct parallel lines, one of them being somewhat stronger and thus suggesting a keel structure. These parallel lines have already been illustrated by GRUNOW (l. c.) who interpreted one of them as a keel, thence placing it into the genus *Nitzschia*.

PERAGALLO (1897, p. 271) mentions the difficulty of finding the proper taxonomical position of the discussed form and unites it with *Nitzschia angustata* in a special group: *Nitzschiae angustatae*, which group shows perhaps a relationship to his genus *Pseudo-Nitzschia*. The latter probably includes — according to PERAGALLO — the intermediate forms between *Synedra* and *Nitzschia*. Really clear genus characters are however lacking and it appears more or less a matter of taste whether to include a species with uncertain keel- or raphe-structures in *Pseudo-Nitzschia* or *Nitzschia*.

In all specimens investigated, the parallel lines were found to be very distinct, giving the definite impression that one of them is a double-line. — Since HUSTEDT's (1928, 1929) investigations, such double-lines are known as ribs enclosing a *Nitzschia*-keel on both sides.

A »normal» valve view, *i. e.* when the valve lies on the cover with the whole of its surface, shows that one of the margins (as said before) is accompanied by a stronger, the other by a more delicate parallel line. In an oblique position of the valve (which is very rare) the »stronger» parallel line shows to be a probably very flat keel with a canal raphe (HUSTEDT's »Kanalraphe») bordered by 2 hyaline parallel lines and underlying dots (HUSTEDT's »Tüpfel» cf. Pl. III, fig. 38 and 39); unfortunately the whole is very difficult to illustrate photographically because of the thickness of the valve and its curvature.[1]) The formation is probably identical with the type which HUSTEDT describes as »Nitzschia-type» (cf. HUSTEDT 1929, Pl. 3, fig. 3 a). At all events, I could not detect, even in fragments in a favourable position, a keel fissure or central pores.

Contrary to the previous, the »more delicate» line along the margin (probably without keel) may be due to the fact that this margin is usually bent sharply towards the inside of the valve. A direct observation is very difficult, but the rarely irregular course of the line may suggest a crease.

In a recently published work HUSTEDT (1952) resumes his observations on *Fragilariopsis kerguelensis* (O'Mea.) = *Fragilariopsis antarctica* (Castr.) Hust. and on types of the raphe within this group. HUSTEDT thinks that the

[1]) The illustration of *Nitzschia marina* in LOHMAN's work (1941, Pl. 17, fig. 11) being much better than our photograph, his excellent microgram should in this connection be expecially referred to.

type of raphe of this species does not correspond with that of the genera *Nitzschia* or *Epithemia;* therefore he includes these forms in the genus *Pseudonitzschia* for the time being.

It is very possible that HUSTEDT's assumption of a different raphe type for the said group of forms is correct. In this connection I would mention that species of the sub-genus *Tryblionella*, as *e. g. Nitzschia angustata* certainly do not show a typical *Nitzschia*-raphe either; but these forms are also difficult to unite with the characteristically marked *Fragilariopsis*- and *Nitzschia marina*-forms. Cf. hereto, the discussion on *Pseudoeunotia*.

In one important point HUSTEDT's and my observations differ. HUSTEDT (1. c.) observed in *Fragilariopsis kerguelensis* the above mentioned parallel lines, or, as he says: » . . . man hat den Eindruck, dass beide Schalenränder einander nicht völlig gleichen, der eine Rand ist etwas breiter und dichter, so dass die Möglichkeit besteht, dass sich an einem Schalenrand eine feine Kanalraphe befindet . . .» (l. c. p. 295). In other words: HUSTEDT observed in *Fragilariopsis* a formation corresponding to that of *Nitzschia marina* just described.

Consequently, I reviewed the rich material of the »Gauss» Expedition and found in no case a dissimilarity of the borders of *Fragilariopsis* or the presence of parallel lines. The borders always appeared to be symmetrical, usually even having a narrow homogene marginal band. The valve marking of *Fragilariopsis kerguelensis*, — very similar to that of the discussed *Nitzschia marina* but much coarser —, I consider only as a convergency which has nothing to do with a real relationship and the genus *Fragilariopsis* can, in my opinion, very well be maintained and be placed within the genuine *Fragilarioideae*.

Considering the uncertainty of the definition of the vague genus *Pseudonitschia* on the one hand and the probability that the discussed form *Nitzschia marina* shows a real keel, its seems correct to me

1. to accept the present species as GRUNOW's *Nitzschia marina* and
2. to draw in the names listed above as synonyms of this form.

In his excellent work, LOHMAN (1941) determines the discussed form as *Nitzschia marina;* it was frequently met with in some of the bottom samples from the North Atlantic, but was not widespread.

FRENGUELLI (1949, p. 118, Pl. 1, fig. 6—7) describes *Pseudonitzschia fossilis* which largely resembles the discussed form; the essential difference is, compared with *Nitzschia marina*, that his form has s i n g l e rows of *punctae* and the dots are more widely spaced (14 in 10 μ) than those of the latter form (16—19 in 10 μ).

Regarding VAN HEURCK's (1. c.) form: *Fragilaria sublinearis* already PERAGALLO (1921, p. 68) expressed some scepticism, pointing out that this species should be included in the genus *Pseudo-Nitzschia;* according to what has been said above, it should be reasonable to consider this form as identical with *Nitzschia marina*.

In the Equatorial Pacific *Nitzschia marina* occurs in almost all diatomiferous cores and in most sediment layers ± abundantly.

Opephora Petit

Opephora pacifica (Grun.) Petit

VAN HEURCK 1880, Pl. 44, fig. 20—22.

HUSTEDT 1927, II, p. 135.

In the few specimens of this species which were found, the transapical ribs were essentially wider spaced (3—4 in 10 μ) than stated in the diagnoses (6 in 10 μ) but could not, however, be mistaken for *Opephora gemmata* (Grun.) Hust.

This epiphytic species has also been found in Core 38/100 only, near the Galapagos Islands.

Plagiogramma Grev.

Plagiogramma pulchellum var. *pygmaea* (Grev.) Perag.

Peragallo 1897, p. 338, Pl. 82, fig. 3.

Hustedt 1927, II, p. 108.

Locality: Core 39/461.

Plagiogramma staurophorum var. *robustum* (Brun) Hust.

Brun 1889, p. 47, Pl. 9, fig. 7.

Hustedt 1927, II, p. 110.

Locality: Core 39/2.

The two representatives of the benthonic genus *Plagiogramma* were collected only at one ± nearshore locality (Galapagos Islands).

Pleurosigma W. Sm.

Pleurosigma nicobaricum Grun.

Peragallo 1890, Pl. 4, fig. 10.

Cleve 1894, I, p. 36.

The species has been observed exclusively in Core 76, in most of its sediment layers, although it occurred comparatively seldom.

Pleurosigma nicobaricum var. *sagitta* Br. & Temp.

Peragallo 1890, Pl. 4, fig. 9.

Cleve 1894, I, p. 36.

Localities: Cores 60/966, 76/1189.

Podocystis Ktz.

Podocystis adriatica Ktz.

Peragallo 1897, Pl. 68, fig. 11.

Hustedt 1927, II, p. 131.

Of the two species belonging to the genus *Podocystis*, according to the statement by Hustedt (l. c.), *P. adriatica* occurs especially in the Atlantic and *P. spathulata* in the shore regions of the Pacific. One was therefore prepared to find the latter species in the present material. This was, however, not the case; the typical sculpture of the observed form — several rows of areolae between the transapical ribs — could not cause any doubts about its being identical with *P. adriatica*.

Localities: as most littoral forms — only in the region of the Galapagos Islands: Core40/350.

Pseudoeunotia Grun.

In the Equatorial Pacific — especially in the proximity of the Galapagos Islands — the only representative of the genus: *Pseudoeunotia doliolus* occurring very frequently could be studied more closely.

Pseudoeunotia doliolus (Wall.) Grun.

Wallich 1860, Pl. 2, fig. 19.

Peragallo 1897, Pl. 82, fig. 27.

Lohman 1941, Pl. 17, fig. 12, 13 (excellent microgram).

Hustedt 1927, II, p. 258.

Icon nostr. Pl. III, fig. 41.

The form is in structure — apart from the curvature of its bent apical axis — extremely similar to *Nitzschia marina* (cf. the discussion on this species). The frustule presents in valve view — generally only f r u s t u l e s are met with — always parallel lines along the borders, (especially the convex one?) which may indicate the presence of a keel; these lines are not to be mistaken for simple marginal lines such as they appear on forms lacking keels, as *e. g. Synedra crystallina*, occurring in the same material.

The parallel lines in *Pseudoeunotia doliolus* have already been drawn by Wallich (l. c.); Peragallo (l. c.) illustrated them very distinctly.

To prove the existence of a keel is, for this form, still more difficult than for *Nitzschia marina*. The valve margin (the »gable» or »Dachkante» of German authors) is evidently very acute and the eventual keel is pushed to the utmost ridge; the narrow side of the valve is evidently very narrow and the whole structure very delicate. Moreover, owing to its structure, the species has a tendency to lie with its broad side on the cover and it is almost impossible to find a specimen lying in a suitable position. After studying many specimens I got the definite impression that the form has a similar anatomy as *Nitzschia marina*.

On account of these observations I recommend to incorporate the genus *Pseudoeunotia* in the *Nitzschioideae*.

Localities: especially in Cores 38, 39, 40, 41, less frequent also in Cores 47, 58, 59, 60, 61, 62, 74, 75, 98.

Radiopalma J. Brun

Radiopalma dichotoma J. Brun.
Brun 1891, p. 42, Pl. 17, fig. 6 a, b.
Icon nostr. Pl. IV, fig. 47 a, 47 b.

The finding of this characteristic form discovered by Brun in the Tertiary deposits from Moron (Spain, Miocene) is very remarkable. It apears from the literature that the form has been little observed and even in the present material I could only find one complete specimen, unfortunately in a slanting position and therefore difficult to photograph. The shape and structure, with radii bifurcating at the periphery is, however, very typical and the form is thus easily identified.

The finer structure of *Radiopalma* needs a more detailed description. The slightly convex, apparently only thin-walled valve, is covered by a closed network of hexagonal areolae. The density of the areolae, in my specimen, amounts to 10 areolae in 10 μ. The valve shows a great number of rectilinear radii, in the illustrated specimen 47 radii. The radii are fine rib-like t h i c k e n i n g s of the inside of the valve, which is easily proved by lifting and lowering the tubus. Strangely enough, the areolae on the surface of the valve are not influenced by the inside ledges, *i. e.* the network of areolae over the ribs is by no means interrupted by the radii but runs over them as regularly as on the intercostal areas.

The central part of the valve is irregularly circular, about 8 to 10 μ in diameter, eccentrically situated so that the radii are of different lengths. Shortly before reaching the border the radii bifurcate and the intermediate space between the forked ends is formed by a filiform, hyaline and lustrous attenuation of the valve membrane; cf. fig. 47 a. Between the bifurcated radii (always distinct and clean cut), further thin secondary radii are intercalated which can still be seen rather clearly at the periphery, but become less distinct towards the central part of the valve and finally almost disappear near the centre. The girdle is more delicately areolated than the valve (about 12 to 13 areolae in 10 μ).

The diameter of the specimen photographed was about 77 μ; a precise measurement was impossible on account of the sloping position of the valve. The border had no processes or »loculi» as *e. g. Bruniopsis*.

Like most Pre-Quaternary forms, this one was also found in Core 76, which contains most of the material's Tertiary species.

Locality: Core 76/1261.

Rhizosolenia Ehr.

Relatively few fragments of this widespread genus of typical plankton forms were observed in the bottom samples of the Equatorial Pacific. The *copulae* were completely dissolved or reduced into vague fragments. At times only the outermost, strongly silicified *apices* remained, mostly with broken processes of the *calyptra*. A definite determination was therefore possible in only a few instances; it being, however, always the same 3 species, one may presume that the three forms below belong to the species most resistant against corrosion in our area.

Rhizosolenia bergonii Per.
Peragallo 1892, p. 110, Pl. 15, fig. 5.
Hustedt 1927, I, p. 575.
Localities: Cores 58/742, 58/845, 58/920, 59/0, 61/908, 74/1242.

Rhizosolenia firma Karst.
Hustedt 1927, I, p. 574.
Localities: Cores 61/100, 61/661, 61/861, 74/332, 74/722.

Rhizosolenia styliformis Brightw.
Peragallo 1892, p. 111.
Hustedt 1927, I, p. 584.
Localities: Cores 38/80, 76/1221, 76/1241.

Roperia Grun.

Roperia tesselata (Rop.) Grun.

VAN HEURCK 1880, Pl. 118, fig. 6, 7.

HUSTEDT 1927, I, p. 523.

Widespread in the material; more frequent in the sediments of the Eastern Pacific, more rare towards the west.

Localities: Cores 38, 39, 40, 41, 58, 59, 60, 61, 62, 74, 75, 93, 105.

MANN (1937, p. 19, Pl. 1, fig. 5) described a form which he named *Actinocyclus coscinodiscoides*. The areolation of the illustrated form is quite different from the structure of the known species of *Actinocyclus*, which mostly show a clear radial structure. MANN's illustration is very similar to some typical *Roperia*-specimens, which I so frequently observed and in my opinion *Actinocyclus coscinodiscoides* Mann and *Roperia tesselata* (Rop.) Grun. are identical. In many individuals of the present bottom samples I occasionally observed a somewhat stronger fasciculation than drawn by MANN.

Roperia tesselata f. *elliptica* nov. f.

Besides the species, an elliptical form was comparatively frequent in the samples examined; it was (although rarely) connected by transitions with the species.

Roperia tesselata f. *elliptica* differs from the typical form by its irregular broadly elliptical outline and its considerable size; the largest measured specimens were 103 μ long and 68 μ broad; the most frequent dimensions were about 70×55 μ. The ocellus is usually placed in the centre of the long valve-side, somewhat off the border.

The form is very like *Actinocyclus roperi* (missing in the present material), but differing from this species by:

1. a much larger ocellus — its diameter being about 3 μ
2. by the absence of a central rosette
3. a wider areolation (5—6 as compared to 16 areolae in 10 μ for *Actinocyclus roperi*),
4. no fasciculate or radial disposition of the areolae.

Localities: Cores 39, 40, 58, 62, 74.

Roperia tesselata var. *ovata* (Mann) nov. comb.

MANN 1925, p. 143, Pl. 31, fig. 3 (= f. ovata).

Synonym: *Roperia tesselata* var. *ovata* Heiden (HEIDEN & KOLBE 1927, p. 507).

The not very frequent specimens from the Equatorial Pacific are fully identical with MANN's form. MANN remarks correctly that the disc border has a »fictitious wavy appearance». The structure, however, is real, as is seen by a closer investigation; at a strong magnification using the best optics (apochromates) one observes that the border rising above the marginal edge is characteristically crenulated, the crests looking exactly like the teeth of a circular saw. Less strongly magnified this crenulation gives the valve a wavy appearance. The crenulation of the border is limited to the broader end of the egg-shaped valve, gradually becoming more shallow and disappearing at the apex of the valve. The ocellus is always situated at the apex.

The three characteristics: egg-shaped outline, crenulation at the broader end and the position of the ocellus at the apex being so characteristic, the form deserves at least the rank of a variety.

For reasons of priority, HEIDEN's identical form had to be drawn in.

Localities: Cores 39/115, 74/565, 91/198, 91/298.

Stictodiscus Grev.

Stictodiscus buryanus var. *gracilis* Tr. & Witt.

TRUAN & WITT 1888, p. 19, Pl. 5, fig. 15.

A. S. Atl. Pl. 442, fig. 3.

Localities: Cores 38/20, 40/350.

Stictodiscus johnsonianus f. *trigona* Tr. & Witt.

TRUAN & WITT 1888, Pl. 5, fig. 9.

A. S. Atl. Pl. 442, fig. 10—12.

Icon nostr. Pl. II, fig. 17.
Locality: Core 38/40.

Stictodiscus parallelus (Ehr.) Gr. & St.
A. S. Atl. Pl. 447, fig. 1—5.
Localities: Cores 38/20, 39/400.

The above three representatives of the benthonic genus *Stictodiscus* were met with in the material only in the proximity of the Galapagos Islands.

Synedra Ehr.

Synedra species — being typical epiphytes — were expected to be found only at the nearshore region of the Galapagos Islands. It was so much the more surprising to meet one of the three species observed, *Synedra tabulata*, in the deeper sediment layers of Core 76 only.

Synedra crystallina (Ag.) Ktz.
Hustedt 1927, II, p. 232.
Locality: Core 40/190.
(?) *Synedra tabulata* (Ag.) Ktz.
Hustedt 1927, II, p. 218.

With regard to its dimensions and outline this form (restricted to Core 76) fully agrees with *Synedra tabulata*. Nevertheless our species appears more delicate and more hyaline than the rather coarsely built *Synedra tabulata;* also the wide longitudinal area between the striae is not quite homogeneous but appears to have an extremely delicate striation and a trace of a filiform raphe (?). These traces of structures may be attributed to corrosion phenomena. On the other hand (and most probably so) it may be a form unknown to me. The rather strange locality near the Tertiary border or even beyond it, may suggest another species than *Syn. tabulata*, the difference between the two being hardly noticeable.

Localities: only in Core 76 from the level 741 cm to the end of the core (1342 cm).

Synedra undulata Bail.
Hustedt 1927, II, p. 224.
Locality: Core 39/322, one specimen only.

Thalassionema Grun.

In the present material *Thalassionema* and *Thalassiothrix* were met with chiefly as fragments. A reliable determination of these fragments was not always possible and the exact locality for the one or the other species of the two genera was for this reason also uncertain; no separate localities are mentioned therefore. (cf. Table 2, 3, 4).

Thalassionema nitzschioides Grun.
Hustedt 1927, II, p. 244.
van Heurck 1881, Pl. 43, fig. 6—12.
Thalassionema nitzschioides var. *parva* Heid.
Heiden & Kolbe 1927, p. 564, Pl. 5, fig. 118.
Synonyms: *Thalassionema nitzschioides* var. *inflata* Heid. *Thalassionema nitzschioides* var. *incurvata* Heid.

The last mentioned varieties do not even deserve the rank of forms. In all localities of var. *parva* they can always be found as transitory forms.

Localities: in most cores together with *Thalassiothrix*.

Thalassiosira Cleve

Thalassiosira decipiens (Grun.) Jörgensen.
van Heurck 1880, Pl. 91, fig. 10.
Hustedt 1927, I, p. 322.
Localities: Cores 38, 39, 40, 59, 60, 61, 62, 74, 75, 105.

Thalassiothrix Cl. & Grun.

Thalassiothrix longissima Cl. & Grun.
Hustedt 1927, II, p. 246.

By far most of the fragments in the present material lacked the terminal spines and so were difficult to differentiate from *Thalassionema*.

Both genera are widespread and abundant in most cores of the present material.

Trachyneis Cleve.

Trachyneis aspera (Ehr.) Cl.
Peragallo 1897, Pl. 29, fig. 1, 2.
Locality: Core 39/115 only a few specimens.

Triceratium Ehr.

Triceratium antediluvianum (Ehr.) Grun.

Van Heurck 1880, Pl. 109, fig. 4, 5.

A. S. Atl. Pl. 99, fig. 1—4, 6—9.

Hustedt 1927, I, p. 810.

Locality: Core 39/186.

Triceratium balearicum f. *biquadrata* (Jan.) Hust.

A. S. Atl. Pl. 98, fig. 4.

Hustedt 1927, I, p. 815.

Locality: Core 39/186.

Triceratium cinnamomeum Grev.

Van Heurck 1880, Pl. 126, fig. 1.

Icon nostr. Pl. II, fig. 18.

Synonyms: *Cestodiscus cinnamomeus* (Grev.) Grun. in Van Heurck 1880, explanation to Pl. 126, fig. 1;

Pseudotriceratium cinnamomeum (Grev.) Grun. Grunow 1884, p. 31.

Trigonium cinnamomeum (Grev.) Grun. Mann 1888, p. 292.

Regarding the taxonomy of this form, as well as of the genus *Triceratium* in general, I agree with Hustedts's (1927, I, p. 793 ff.) conception. In my opinion the actinomorphy is the characteristic feature of the genus *Triceratium*. The retention of the genus *Triceratium* seems therefore justified. On the other hand, I consider the creation of the genera *Pseudotriceratium* or *Trigonium* for some species ± lacking apiculi or gibbosities unsuitable, especially for practical reasons, as it is more often than not impossible to arrive at any definite decision with regard to the anatomical peculiarities of these — usually minute — forms.

Whereas the two preceding forms, as typical littoral diatoms, were restricted to the cores around the Galapagos Islands, *Triceratium cinnamomeum* and var. *minor* are spread over the whole region, never markedly abundant but are nevertheless two of the most constant forms of the Equatorial Pacific.

Localities: core 38, 40, 41, 42, 47, 58, 59, 60, 61, 62, 74, 75, 76.

Triceratium cinnamomeum var. *minor* Grun.

Van Heurck 1880, Pl. 126, fig. 2.

Icon nostr. Pl. II, fig. 20.

Localities: at the same localities and more frequent than the typical form.

Triceratium cinnamomeum f. *quadrangulata* Grun.

Van Heurck 1880, explanation to Pl. 126, fig. 1

Icon nostr. Pl. II, fig. 19.

In the explanation of his figure, Grunow (in Van Heurck, l. c.) remarks: »on trouve une forme quadrangulaire dans le dépôt de Naparima; les épines du bord sont souvent très petites, parfois à peine visibles.»

The specimen illustrated here has an apical length (measured between 2 apices) of 82 μ, areolae 6 in 10 μ.

One locality only: Core 76/23.

As far as I know, the form is hitherto only known from the diatomite of Naparima (Trinidad, upper(?) Eocene). In the present material it is Core 76, which contains most Pre-Quaternary forms and it is hardly a mere coincidence that this remarkable form was also met with in the same Core 76.

Latin diagnoses of new forms.

Asterolampra arrhenii nov. sp.

Icon nostr.: fig. 8 et tab. IV, fig. 43.

Valvae reniformes, planae, fragiles, 138—216 μ longae, 84—150 μ latae; area centralis circularis hyalina, radiis 8—14 rectis, interdum bifurcatis; compartimentes circiter 3/4 radii occupantes, centrum versus convexi vel truncati, areolis distinctis aequalibus 12 in 10 μ; intervalla (vectores) 8—14, aequilata (circiter 3 μ), leviter arcuato-curvata vel recta, marginem non attingentes.

Cestodiscus pulchellus var. *maculatus* nov. var.

Icon nostr.: tab. I, fig. 8.

Valvae planae, diametro 47—94 μ, margine abrupto, distincte striato (8—10 in 10 μ), 2.5—3 μ lato; structura areolis circulis concentricis undulatis constituens, maculis interareolaribus obscuris praeditis.

Cladogramma pacifica nov. sp.

Icon nostr.: tab. III, fig. 34.

Forma minuta, circularis (diametro 21 μ), valvis planis, e centro parvo rotundato radiis sat grossis asteriformibus, marginem versus multifidis, margine ipso indistincte striato (striis marginalibus circiter 20 in 10 μ).

Coscinodiscus lineatus var. *ellipticus* nov. var.

Icon nostr.: tab. II, fig. 15.

Valvae ellipticae 50—96 μ longae, 44—80 μ latae, areolis 5—6 in 10 μ, margine striato 9—11 in 10 μ).

Liriogramma nov. gen.

Valvae planae, sublanceolatae vel oviformes; striae longitudinales distincte punctatae, paullo irregulares; striae transversales obliquae, pseudoraphe distincta. Medium valvae e structura magna perconspiqua, hyalina, valdeque refringenti compositum, liliae deformatae partum 6 (liliae Bourbonorum »fleur de lis») sat similis.

Liriogramma petterssonii nov. sp.

Icon nostr.: fig. 9 et tab. IV, fig. 46 a et 46b.

Characteres generis. Longitudo 56 μ, latitudo 16 μ, striae longitudinales 10 in 10 μ.

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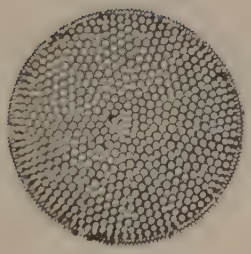
PLATES

PLATE I.

Fig. 1. *Coscinodiscus curvatulus* Gr. Locality: Core 76/1198 ..... 500: 1
Fig. 2. *Coscinodiscus excavatus* var. *quadriocellatus* Gr. Locality: Core 76/23 540: 1
Fig. 3. *Asterolampra moronensis* Grev. Locality: Core 76/581 ..... 700: 1
Fig. 4. *Craspedodiscus coscinodiscus* Ehr. Locality: Core 76/1198 ..... 500: 1
Fig. 5. *Liostephania* 1. Locality: Core 76/581 ..... 1500: 1
Fig. 6. *Liostephania* 2. Locality: Core 76/1201 ..... 1000: 1
Fig. 7. *Liostephania* 3. Locality: Core 76/1221 ..... 700: 1
Fig. 8. *Cestodiscus pulchellus* var. *maculatus* nov. var. Locality: Core 76/1321 500: 1
Fig. 9. *Coscinodiscus aeginensis* A. Schm. (?) Locality: Core 76/23 ..... 600: 1
Fig. 10. *Coscinodiscus aeginensis* A. Schm. (?) Locality: Core 76/23 ..... 500: 1
Fig. 11. *Coscinodiscus tuberculatus* Grev. Locality: Core 76/1001 ..... 700: 1
Fig. 12. *Coscinodiscus tabularis* Gr. Locality: Core 39/461 ..... 1500: 1
Fig. 13. *Coscinodiscus vigilans* A. Schm. Focus on pore membrane. Locality: Core 58/530 ..... 1000: 1
Fig. 14. *Coscinodiscus vigilans* A. Schm. Focus on chamber walls. Locality: Core 76/381 ..... 1000: 1



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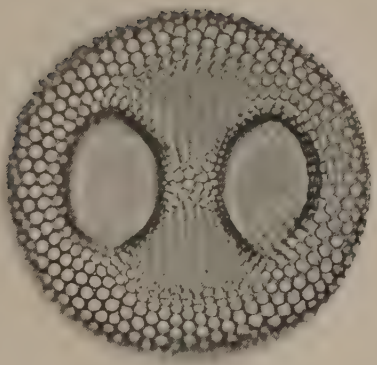

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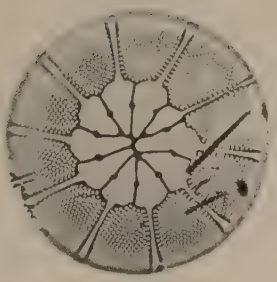

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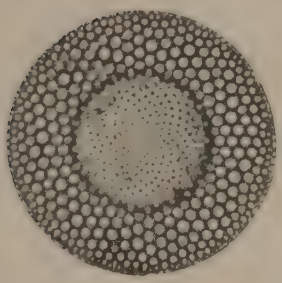

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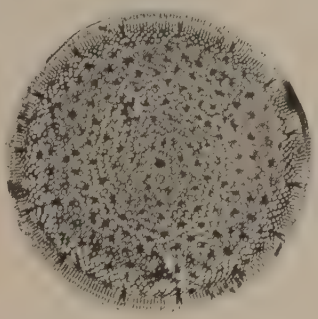

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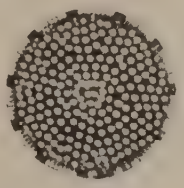

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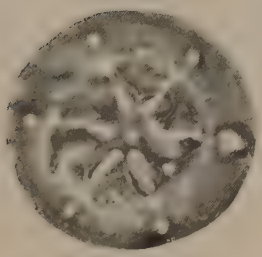

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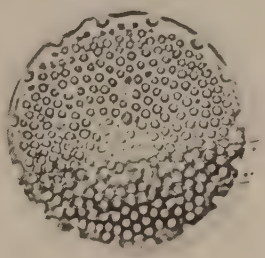

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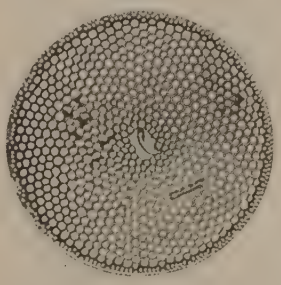

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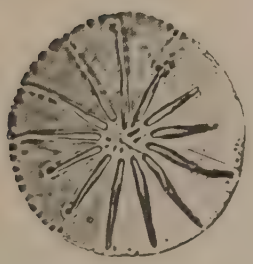

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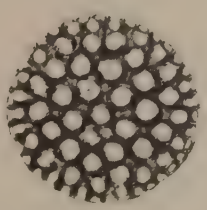

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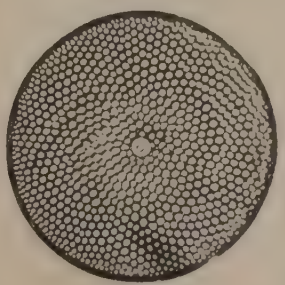

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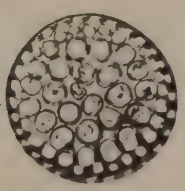

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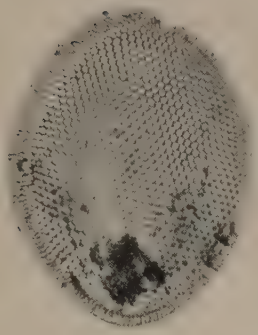
PLATE II.

Fig. 15. *Coscinodiscus lineatus* var. *ellipticus* var. nov. Locality: Core 47/300 .. 700: 1
Fig. 16. *Navicula approximata* Grev. Locality: Core 39/186 ..... 1000: 1
Fig. 17. *Stictodiscus johnsonianus* f. *trigona* Tr. & Witt. Locality: Core 38/40 . 500: 1
Fig. 18. *Triceratium cinnamomeum* Grev. Locality: Core 60/966 ..... 600: 1
Fig. 19. *Triceratium cinnamomeum* f. *quadrangulata* Grun. Locality: Core 76/23 500: 1
Fig. 20. *Triceratium cinnamomeum* var. *minor* Grun. Locality: Core 60/880 .... 1000: 1
Fig. 21. *Coscinodiscus lewisianus* Grev. Locality: Core 59/890 ..... 700: 1
Fig. 22. *Coscinodiscus lewisianus* var. *similis* Rattr. Locality: Core 58/890 .... 1000: 1
Fig. 23. *Coscinodiscus lanceolatus* Castr., small specimen. Locality: Core 58/623 1000: 1
Fig. 24. *Coscinodiscus lanceolatus* Castr. focus on sieve membrane. Locality: Core 59/747 ..... 1000: 1
Fig. 25. Same specimen as fig. 24, but focus on pore membrane. Locality: Core 59/747 ..... 750: 1



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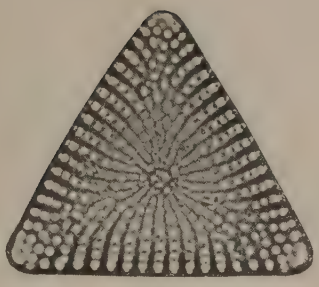

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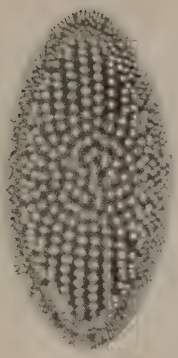

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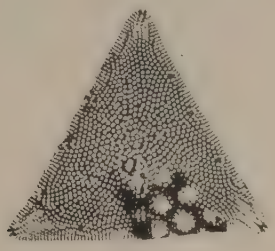

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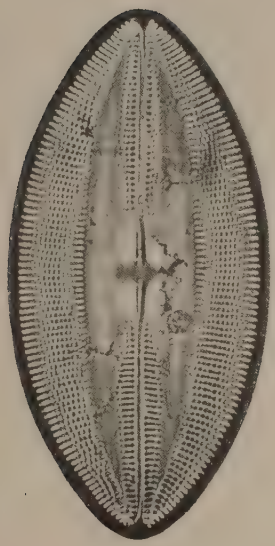

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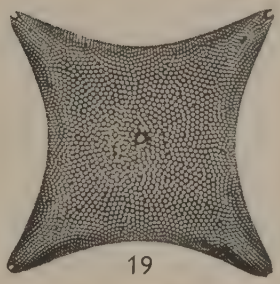

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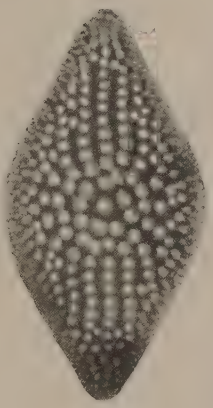

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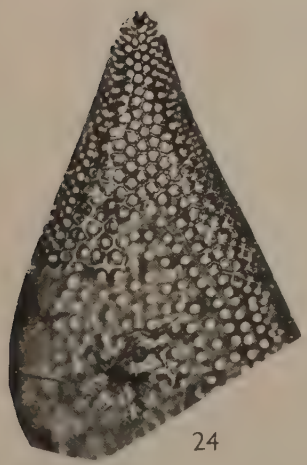

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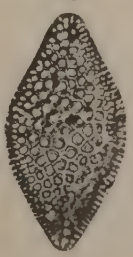

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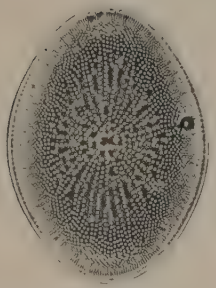
PLATE III.

Fig. 26. *Actinocyclus ellipticus* Grun (typ.) Locality: Core 76/1198 ..... 500: 1
Fig. 27. *Actinocyclus ellipticus* f. *lanceclata* nov. f. Locality: Core 60/966 ..... 600: 1
Fig. 28. *Actinocyclus ellipticus* var. *elongatus* (Grun.) Locality: Core 60/656 .. 1000: 1
Fig. 29. *Actinocyclus ellipticus* var. *moronensis* (Grun.) Locality: Core 76/841 600: 1
Fig. 30. *Actinocyclus ellipticus* var. *moronensis*, intermediate form. Locality: Core 76/23 ..... 600: 1
Fig. 31. *Actinocyclus ellipticus* var. *elongatus*, fig. 28 enlarged to show ocellus 2000: 1
Fig. 32a. *Coscinodiscus paleaceus* (Grun.) Rattr. Locality: Core 76/1001 ..... 800: 1
Fig. 32b. *Coscinodiscus paleaceus* (Grun.) Rattr. Locality: Core 60/535 ..... 1000: 1
Fig. 33. *Glyphodesmis williamsonii* f. *inflata* nov. f. Locality: Core 38/120 ..... 1000: 1
Fig. 34. *Cladogramma pacificum* nov. sp. Locality: Core 60/447 ..... 1500: 1
Fig. 35. *Coscinodiscus nodulifer* A. Schm. Locality: Core 74/272 ..... 350: 1
Fig. 36. *Coscinodiscus nodulifer* A. Schm. specimens of different size. Locality: Core 74/272 ..... 350: 1
Fig. 37. *Coscinodiscus nodulifer* A. Schm. »ring» cf. p. XX Locality: Core 74/398 300: 1
Fig. 38. *Nitzschia marina* Grun., the entire valve. Locality: Core 74/272 ..... 750: 1
Fig. 39. *Nitzschia marina*, the end of the valve. Locality: Core 74/1202 .... 1300: 1
Fig. 40. *Nitzschia marina*, same specimen as fig. 39, fragment. Locality: Core 74/1202 ..... 1300: 1
Fig. 41. *Pseudoeunotia doliolus* (Wall.) Grun. Locality: Core 48/400 ..... 1000: 1



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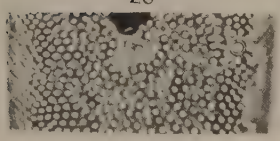

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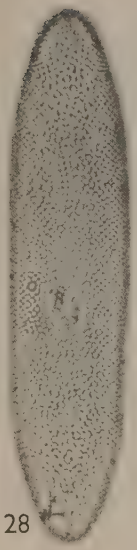

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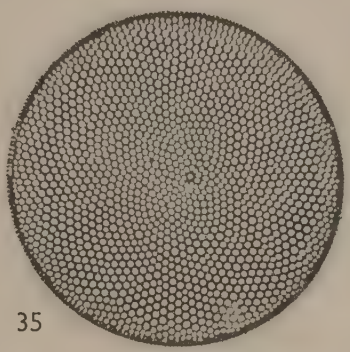

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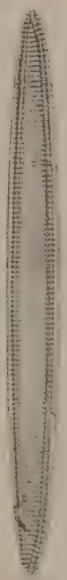

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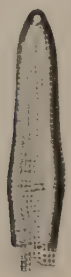

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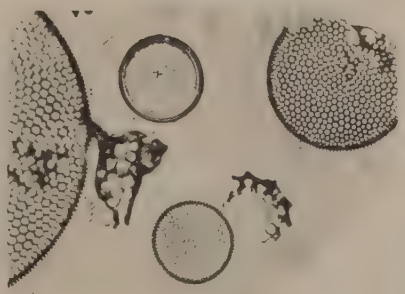

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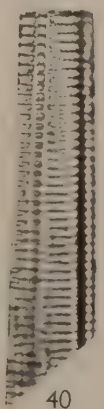

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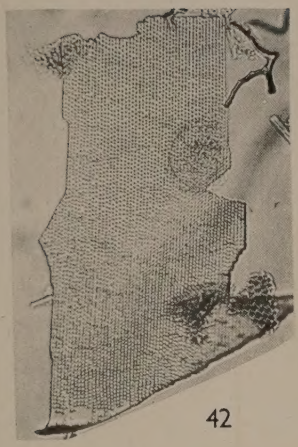
PLATE IV.

Fig. 42. »Fragment» cf. p. 37 Locality: Core 38/280 ..... 400: 1
Fig. 43. *Asterolampra arrhenii* nov. sp. Locality: care 76/541 ..... 340: 1
Fig. 44a. *Bruniopsis mirabilis* (Brun) Karst., margin of valve. Locality: Core 76/1001 ..... 700: 1
Fig. 44b. *Bruniopsis mirabilis* (Brun) Karst., larger fragment. Locality: Core 76/1061 ..... 300: 1
Fig. 45. *Coscinodiscus gigas* Ehr., partial view. Locality: Core 76/1188 ..... 450: 1
Fig. 46a. *Liriogramma petterssonii* nov., gen, nov. sp. Locality: Core 38/160 ... 1000: 1
Fig. 46b. *Liriogramma petterssonii*, same specimen as fig. 46a. Locality: Core 38/160 ..... 1600: 1
Fig. 47a. *Radiopalma dichotoma* Brun. Locality: Core 76/1261 ..... 750: 1
Fig. 47b. *Radiopalma dichotoma* Brun, same specimen as fig. 47a. Locality: Core 76/1261 ..... 500: 1
Fig. 48. *Hemidiscus cuneiformis* Wall., Colony. Locality: Core 61/908 ..... 500: 1



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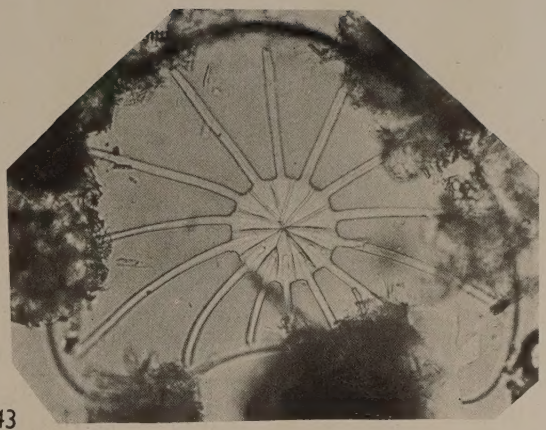

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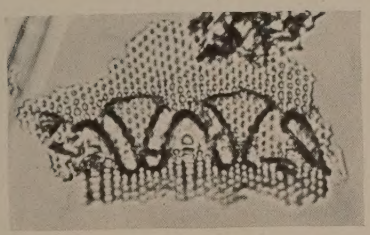

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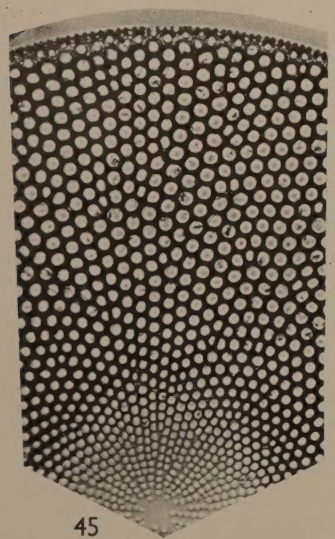

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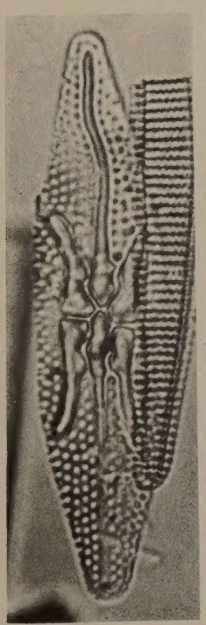

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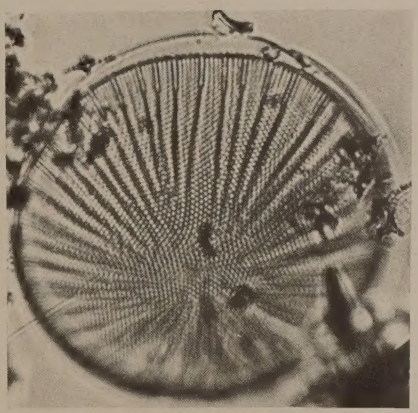

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